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SHUTTLE VEHICLE AND MISSION SIMULATION REQUIREMENTS REPORT

VOLUME IV

10/20/72

SINGER
SIMULATION PRODUCTS

A DIVISION OF THE SINGER COMPANY • DEVELOPER AND MANUFACTURER OF THE LINK TRAINER SINCE 1929

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SHUTTLE VEHICLE AND MISSION

SIMULATION REQUIREMENTS REPORT

VOLUME IV

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J. F. Burke
Principal Investigator
SMS Definition Study

This document is submitted in compliance with Line Item No. 2 of the Data Requirements List as Type I Data, Contract NAS 9-12836

SINGER COMPANY
SIMULATION PRODUCTS DIVISION

SHUTTLE VEHICLE AND MISSION SIMULATION REQUIREMENTS REPORT

VOLUME IV

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PREFACE

This document is submitted in compliance with Line Item No. 2 of the Data Requirements List as Type I Data, Contract NAS9-12836. The document is divided into four volumes for ease of handling. The contents of each volume is defined as:

Volume I: Includes sections entitled Introduction, Mission Envelope and Flight Dynamics which correspond to Sections 1.0, 2.0 and 3.0 of the Table of Contents.

Volume II: Includes sections entitled Introduction and Shuttle Vehicle Systems which correspond to sections 1.0 and 4.0 to 4.18 of the Table of Contents.

Volume III: Includes sections entitled Introduction and Shuttle Vehicle Systems which correspond to sections 1.0 and 4.19 to 4.22 of the Table of Contents.

Volume IV: Includes sections entitled External Interfaces, Crew Prodedures, Crew Station, Visual Cues and Aural Cues which correspond to sections 5.0, 6.0, 7.0, 8.0 and 9.0 of the Table of Contents.

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1.0 Introduction

The objective of the Shuttle Vehicle and Mission Simulation Requirements report is to provide to NASA/MSC documentation of the requirements for faithful simulation of the Shuttle Vehicle, its systems, mission, operations and interfaces. To accomplish this objective the report was divided into eight topics which comprehensively cover the simulation requirements of the Shuttle mission and vehicle. The topics and their main objectives are summarized below.

Mission Envelope - This topic covers the space and atmospheric missions that are envisioned for the Shuttle program. The characteristics of each mission are described by an analysis of the mission phases, trajectory information, timelines and operations for nominal and abort conditions to the extent data was available.

Orbiter Flight Dynamics - This topic covers the flight regimes which the Shuttle vehicle will encounter in the accomplishment of its missions. The requirements were established in the following manner.

The vehicle configurations that must be simulated for horizontal and vertical test flights, operational space missions, atmospheric missions and abort modes were defined.

The dynamics requirements were established by defining the forces and moments that will act on the vehicle during the entire mission envelope which include, propulsion, gravity, aerodynamic effects, payload effects, docking effects, staging effects, ground reactions and the dumping of material overboard. The translational equations of motion requirements were established by defining the vehicles, satellites and payloads whose state vectors must be calculated and by defining the co-ordinate systems, relative equations of motion and accuracy of the calculations. A similar analysis was performed for the rotational equations of motion. Mass property and ephemeris requirements were also identified.

<u>Shuttle Vehicle Systems</u> - The Shuttle vehicle systems required for simulation were identified and described. The descriptive data generated in this effort was primarily based on the North American Shuttle proposal. The Shuttle vehicle and its system configuration is currently in a state of flux and therefore the descriptive data

contained in this report undoubtedly will become out of date as the Shuttle program progresses. However, for the purposes of this study, the data is more than adequate to define simulator requirements and a baseline design when it is tempered with the past experience of Apollo and Gemini programs. A cross correlation between the NR definition of systems and LRU's and this report is shown in Table 1-1 for reference purposes.

External Interfaces - The external interfaces of the Shuttle vehicle were identified and a preliminary type interface description established. Due to the fact that for every external interface there also exists an equivalent on-board system, the descriptive data on the workings of the interfaces is contained in the Shuttle Vehicle Systems section of the report and cross references are provided in this section.

Crew Procedures - The actual crew procedures for the Shuttle system will not be available for many years. As a result the study concentrated on identifying tasks by mission phase and crew member and identifying the probable interfaces between work stations. The data used for the

analysis was a RTOP study by MacDonald-Douglas, conversations with George Franklin of NASA/MSC, past experience, and the requirements of the Shuttle vehicle & mission.

<u>Crew Station</u> - The latest available data at the time of the writing of this report was used to identify the configuration of the Crew Station. The shape of the interior cabin, the location of the work stations and the allocation of the C&D panels by work station were established. Detailed data on the interior composition of the cabin is not currently available. However, simulation requirements were identified based on past experience and accepted levels of fidelity for mission simulators.

<u>Visual Cues</u> - The visual scene content was established for each of the mission phases. Attributes of the scene elements, to the extent feasible, were established and will be further defined in the SMSR report. The vehicle window configuration is not defined at this time but the best data available was utilized. The accelerations, velocites and displacements were established to the extent possible. Some

dynamics data was not available such as in the Abort phases of the mission. The missing information will be incorporated if it becomes available when the time frame and ground rules of the study or assumptions will be made.

<u>Aural Cues</u> - The aural cues requirements associated with the mission and vehicle systems were identified and described. Detailed data on the characteristics of each sound was not available and probably will not be until the vehicle test program is in progress. This factor can be circumvented by specifying flexibility into the simulator aural cue equipment.

This report will be updated at the end of the study based on data received as of January 1, 1972.

Reference to study data sources are included in the margins and the text in order to facilitate update of this report. The numerical references are correlated with the data listing defined by Table 1-2.

TABLE 1-1
SPACE SHUTTLE ON-BOARD EQUIPMENT **CROSS REFERENCES**

SYSTEM: AVIONICS

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	/Remarks/Assumptions
Star Sensor	3	4.9	ITT Model used on Aero Bee but does not meet proposed specs. Specs. and data required.
Rate Sensor Package	3	4.9	Honeywell GG 1027 Model used on F-14 AFCS. Data and Specs. required
Angle of Attack Transducer	3	4.9	Honeywell HG 280 used on DC 10.
IMU	3	4.9	Singer model KT70 used on A7D/E.
IMU Power Supply	3	4.9	Singer model KT70 used on A7D/E.
TVC Monitor	2 (?)	4.9.	No Data Exact function not known.
Air Data Package	3 (?)	4.9. 4.9.	Honeywell Model HG280 used on DC10.
MPS TVC Drivers	3	4.3, 4.9,	No Data Available
Manual TVC/RCS Control	1	4.9,	Honeywell Model BG 286 used on Apollo SCS.
Aero Control Electronics Unit	?	4.9.	Honeywell AFCS used on F-14.
Horizon Sensor Assembly	3	4.9.	Barnes Model 15-163
OMS/TVC Driver Unit	3(?)	4.9..	No Data Available

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: AVIONICS

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks /Assumptions
APS Driver/Monitor	3	4.9	Honeywell Model BG.287 used on Apollo SCS.
Accelerometer Package	3	4.9	Honeywell Model G.G.1026 used on F-14 AFCS
Aero Back-up Electronics	1	4.9	No Data available
Subsystem Sequence Controller	2(?)	4.9	To be used for unmanned flights. No data available
Gyro Accelerometer Package	1	4.9	No Data Available
Backup Optical Unit	1	4.9	Apollo COAS
Throttle/Speed Brake Electronics	?		No Data
GN &C Computer	3(?)	4.1.8.3	IBM Model AP101 or Singer/Kearfott SKC2000.
Program I/O Processor	(?)		IBM SP1
FDAI/EDA	(?)		Honeywell JG 264/BG 285 used on Apollo SCS.
FCS Control Panel	(?)		Honeywell F-14

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TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: ELECTRICAL POWER

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
BATTERY	2	4.1 ELECTRICAL POWER	NICKEL-CADIUM - 10 AMPHOUR - 28 VOLT
GENERATOR CONTROL UNIT	3	4.1 ELECTRICAL POWER	APU DRIVEN GENERATOR
TRANSFORMER RECTIFIER UNIT	3	4.1 ELECTRICAL POWER	150 AMP
REMOTE CONTROL CIRCUIT BREAKER	?	4.1 ELECTRICAL POWER	MAGNETIC LATCH - HERMETIC SEALED UNITS
REMOTE POWER CONTROLLER	4	4.1 ELECTRICAL POWER	MAGNETIC LATCH - HERMETIC SEALED UNITS
BATTERY CHARGES	1	4.1 ELECTRICAL POWER	CONSTANT CURRENT CHARGER - DUAL REDUNDANT OUTPUT
INVERTERS	4	4.1 ELECTRICAL POWER	30, 1250 VA, 115/200V, 400 HZ
SEQUENCERS	2	4.1 ELECTRICAL POWER	NO DATA AVAILABLE
CONTROL TRANSFORMER RECTIFIER	?	4.1 ELECTRICAL POWER	NO DATA AVAILABLE
FUEL CELL	3	4.1 ELECTRICAL POWER	7/10 KW RESTARTABLE - CRYOGENIC 02 and H2 30 VOLT OUTPUT
ALTERNATOR - GENERATOR	3	4.1 ELECTRICAL POWER	20/30 KVA APU DRIVEN SPRAY OIL COOLED WITH INTEGRATED GEARBOX
FUEL CELL HEAT EXCHANGER	3	4.1 ELECTRICAL POWER	

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: MECHANICAL POWER

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
AUXILLARY POWER UNITS	4	4.2.1 AUXILIARY POWER UNITS	200 HORSEPOWER - USES HYDRAZINE
HYDRAZINE TANK	4	4.2.1 AUXILIARY POWER UNITS	NO DATA AVAILABLE
HELIUM TANK	4	4.2.1 AUXILIARY POWER UNITS	NO DATA AVAILABLE
HEAT EXCHANGER	4	4.2.1 AUXILIARY POWER UNITS	NO DATA AVILABLE
HYDRALIC PUMPS	8	4.2.2 HYDRALIC POWER SYSTEM	3000 PSI
ALTERNATOR	3	4.2.1 AUXILIARY POWER UNITS	400 HZ, 30, 20/30 KVA

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TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

STEM: OPERATIONAL INSTRUMENTATION

UIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
PILOT VOICE RECORDER	1	4.11.1 RECORDERS	
SWITCH SCAN MULTIPLEXER	12	FIGURE 4.11-1	
CAUTION AND WARNING	2	FIGURE 4.11-1, 4.11.4	AUTONETICS - APOLLO TYPE (NEW ITEM)
CRASH RECORDER	1	4.11.1 RECORDERS	SUNSTRAND, ECHO SCIENCE, OR DAVOLL FERRY USE ONLY
SIGNAL CONDITIONING UNIT-DFI	17	4.11.2 SENSORS AND SIGNAL CONDITIONING	SAT/APOLLO AUTONETICS SCE
TIMING UNIT (MTU)	2	FIGURE 4.11-1	APOLLO CTE, GENERAL TIMC
LOOP RECORDER	1	FIGURE 4.11-1 4.11.1 RECORDERS	SUNDSTRAND, ECHO SCIENCE, OR DAVOLL (5 MINUTE PLAYBACK)
PCM RECORDER - PAYLOAD	1	FIGURE 4.11-1 4.11.1 RECORDERS	SUNDSTRAND, ECHO SCIENCE OR DAVOLL (MAINT. AND PAYLOAD)
OPER. TRANSDUCERS	2359 DFI 2803 DFI	FIGURE 4.11-1 4.11.2 SENSORS AND SIGNAL CONDITIONING	VARIOUS MAKES
PCM REMOTE UNIT DFI	1	FIGURE 4.11-1	SCI, TELEDYNE
PCM MASTER UNIT - DFI	2	FIGURE 4.11-1	DFI ONLY SCI, TELEDYNE
GROUND CHECKOUT DECODER	?	?	MAY NOT EXIST

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: OPERATIONAL INSTRUMENTATION

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
GN&C COMPUTER 64K	2?	4.18.3	IBM MODEL AP101 OR SINGER/KEARFOTT SKC 2000
INPUT-OUTPUT BUFFER	?	4.18.2.9.3/ 4.18.2.9.4	SP-1 COMPUTER STRUCTURES SKYLAB POWER SUPPLY, AP1/SP1
MDE UNIT	?	4.19-4.19-7	IBM SP1
MAGNETIC TAPE READER	?	4.19.2	NO DATA AVAILABLE
TAPE CONTROL ELECTRONICS	?	4.19.2	NO DATA AVAILABLE
CRT DISPLAY UNIT	8?	4.19.2.1	IBM-F14 TYPE HEAD WITH ADDITION OF A READ/WRITE REFRESH BUFFER, A SYMBOL
			GENERATOR, ANALOG AND DIGITAL CONTROL LOGIC, D/A'S AND POWER SUPPLIES
DFI TIMING UNIT	1		NO DATA AVAILABLE
WIDEBAND RECORDER	1		NO DATA AVAILABLE
FREQUENCY MULTIPLEXER	3		NO DATA AVAILABLE
PCM RECORDER DFI	1		NO DATA AVAILABLE
PCM RECORDER MAINTENANCE	1		NO DATA AVAILABLE

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

YSTEM: OPERATIONAL INSTRUMENTATION

QUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
PCM MASTER UNIT - OFI	2		NO DATA AVAILABLE
PAYLOAD DATA INTERLEAVER	2		NO DATA AVAILABLE
PCM REMOTE ACQUISITION UNIT	24		NO DATA AVAILABLE
DEDICATED SIGNAL CONDITIONER	6		NO DATA AVAILABLE
COMMAND ACQUISITION UNIT	1		NO DATA AVAILABLE

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: D&C

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
VERTICAL SPEED	2	Note: The SV&MSR did not address detailed D&C instruments due to the lack of firm data	BENDIX E-C, AAK-23/A24G-17A
BARO ALTITUDE	2	NO DATA AVAILABLE	AEROSONICS, AAU-16/A
IAS/MACH	2	NO DATA AVAILABLE	BENDIX E-C, ASK-14/A24G-18
FDAI (3 AXIS)	2	NO DATA AVAILABLE	MODIFIED APOLLO CM FDAI
HSI	2	NO DATA AVAILABLE	BENDIX E-C, ACA AQU-4A
TAS/SAT	1	NO DATA AVAILABLE	NO DATA AVAILABLE
ACCELEROMETER	2	NO DATA AVAILABLE	NO DATA AVAILABLE
LG POSITION	1	NO DATA AVAILABLE	3 DISPLAYS - LEFT, RIGHT, NOSE
RCS PRESSURE	3	NO DATA AVAILABLE	DOUBLE POINTER
OMS PC	1	NO DATA AVAILABLE	NO DATA AVAILABLE
OMS FUEL	1	NO DATA AVAILABLE	NO DATA AVAILABLE
OMS OX	1	NO DATA AVAILABLE	NO DATA AVAILABLE

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TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: D&C

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
EVENT TIMER	2	NO DATA AVAILABLE	NO DATA AVAILABLE
HYD. PRESSURE	1	NO DATA AVAILABLE	NO DATA AVAILABLE
MPS PC	1	NO DATA AVAILABLE	NO DATA AVAILABLE
MPS LH2/LO2	1	NO DATA AVAILABLE	NO DATA AVAILABLE
EXT. TANK QUANTITY	1	NO DATA AVAILABLE	NO DATA AVAILABLE
ISS DISAGREE	2	NO DATA AVAILABLE	NO DATA AVAILABLE
CMD DISAGREE	2	NO DATA AVAILABLE	NO DATA AVAILABLE
DRIVER FAIL	2	NO DATA AVAILABLE	NO DATA AVAILABLE

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: COMMUNICATION AND TRACKING

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
SGLS INTERROGATOR	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
VHF TRANSCEIVER	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
ATC TRANSPONDER	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
SGLS TRANSPONDER	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
SGLS DECODER	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
USB TRANSPONDER	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
SIGNAL PROCESSOR	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
AUDIO CONTROL CENTER	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
TACAN TRANSPONDER	3	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
COMMAND DECODER	2	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
RADAR ALTIMETER	3	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
WIDEBAND TRANSMITTER S-BAND	1	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE

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TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

YSTEM: COMMUNICATION AND TRACKING

QUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
S-BAND ANTENNA	4	4.10 COMMUNICATIONS AND TRACKING	HELIX IN CAVITY (RHCP)
C-BAND ANTENNA	6	4.10 COMMUNICATIONS AND TRACKING	HORN (LP) FOR RADAR ALTIMETER
L-BAND ANTENNA	1	4.10 COMMUNICATIONS AND TRACKING	ANNULAR SLOT (VP) FOR TACAN AND ATC
UHF/VHF ANTENNA	3	4.10 COMMUNICATIONS AND TRACKING	HP DUAL CAVITY FOR ILS
VHF ANTENNA	2	4.10 COMMUNICATIONS AND TRACKING	HELIX IN CAVITY (RHCP)
VHF ANTENNA	1	4.10 COMMUNICATIONS AND TRACKING	TOP CAP (VP)
VHF ANTENNA	1	4.10 COMMUNICATIONS AND TRACKING	SPIRAL (VP)
L-BAND ANTENNA	2	4.10 COMMUNICATIONS AND TRACKING	HELIX IN CAVITY (RHCP) FOR TACAN
L-BAND ANTENNA SELECTOR	1	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
VHF ANTENNA SELECTOR	1	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
S-BAND ANTENNA SELECTOR	1	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
CCTV CAMERA (B&W)	4	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: COMMUNICATION AND TRACKING

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
TV CAMERA - COLOR	1	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
DFI TRANSMITTER	1	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
ILS RECEIVER	3	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE
SECURE TERMINAL	4	4.10 COMMUNICATIONS AND TRACKING	NO DATA AVAILABLE

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: AIRBREATHING PROPULSION

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
TURBOFAN ENGINE	4	4.6 AIRBREATHING PROPULSION SYSTEM	P&W F401-PW-400 MODIFIED
FUEL TANK	1,2,or3	4.6 AIRBREATHING PROPULSION SYSTEM	22,565 LBS FOR EACH TANK

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: SOLID ROCKET MOTORS

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
MOTOR	2	4.7.1 MAIN SRM	SOLID PROPELLANT 156"
MOTOR	12	4.7.1 MAIN SRM	SOLID PROPELLANT 27K LBS @ 2 SECONDS
MOTOR	2	4.7.2 ABORT SOLID ROCKET MOTOR	SOLID PROPELLANT 385,000 LBS AVERAGE @ 21 SECONDS
MOTOR	2	4.7.3 DEORBIT SRM FOR EXTERNAL TANK	SOLID PROPELLANT 18,500 LBS @ 37 SECONDS

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TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: EXTERNAL TANK

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
OXYGEN TANK - LIQUID	1	4.8.1 STRUCTURE	
HYDROGEN TANK - LIQUID	1	4.8.1 STRUCTURE	
BATTERY	2	4.8.4 AVIONICS	
ORDINANCE TIMING SYSTEM (DEORBIT AVIONICS)	1	4.8.4 AVIONICS	
RANGE SAFETY AVIONICS	1	4.8.4 AVIONICS	

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TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: MAIN PROPULSION SYSTEM

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
MPS ENGINE INTERFACE UNIT	3	4.3 MAIN PROPULSION SYSTEM	NO DATA AVAILABLE
MPS CONTROLLER	3	4.3 MAIN PROPULSION SYSTEM	NO DATA AVAILABLE
FUEL PREBURNER	3	4.3 MAIN PROPULSION SYSTEM	NO DATA AVAILABLE
OXIDIZER PREBURNER	3	4.3 MAIN PROPULSION SYSTEM	NO DATA AVAILABLE
MAIN ENGINE	3	4.3 MAIN PROPULSION SYSTEM	470K VAC THRUST
ENGINE ACTUATOR	6	4.3.5 ENGINE ACTUATOR	NO DATA AVAILABLE

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TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: REACTION CONTROL SYSTEM

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
REACTION CONTROL MOTOR	40	4.4 REACTION CONTROL SYSTEM	1000 LBS THRUST VAC
HELIUM PRESSURIZATION SPHERES	4	4.4.4 PRESSURIZATION SUBSYSTEM	4000 PSI TANKS
MONOPROPELLANT HYDRAZINE FUEL TANKS	8	4.4 REACTION CONTROL SYSTEM	25 INCH DIAMETER X 42 INCH LONG CYLINDERS

TABLE 1-1

SPACE SHUTTLE ON-BOARD EQUIPMENT CROSS REFERENCES

SYSTEM: ORBITAL MANEUVERING SYSTEM (OMS)

EQUIPMENT	NUMBER OF UNITS	SV & MSR Paragraph Number and Title	Remarks
ENGINE	2	4.5 ORBITAL MANEUVERING SYSTEM	5000 LBS VAC
TANK OXIDIZER	2	4.5 ORBITAL MANEUVERING SYSTEM	12,200 LBS MAX. - NITROGEN TETROXIDE
TANK FUEL	2	4.5 ORBITAL MANEUVERING SYSTEM	12,200 LBS MAX. - MONOMETHYLHYDRAZINE
HELIUM TANK	2	4.5 ORBITAL MANEUVERING SYSTEM	3200 PSIA

SORTED BY INDEX NUMBER

DATA REFERENCES
SHUTTLE MISSION SIMULATOR STUDY

OCTOBER 20, 1972

DOC. SRCE	DOC. DATE	NUMBER	REV	DOCUMENT TITLE	DATE RECD	LOAN	SEQ NO.
GE	15MR72	MSC-03824		SS PHASE B EXTENSION FINAL REPORT-PAYLOAD IMPACT V2A	15JE72	HB	002
NA	25FE72	FM347234		PAN AMERICAN APPROACH TO SHUTTLE CREW SEL/TRNG/ASSIGN	15JE72	HB	003
NA	15MA72	MSC-04217	C	SPACE SHUTTLE GN+C DESIGN EQUATION DOCUMENT	15JE72	HB	004
GE	15MR72	MSC-03824		SS PHASE B EXTENSION FINAL REPORT-MASS PROPERTIES V3	15JE72	HB	005
GE	15MR72	MSC-03824		SS PHASE B EXTENSION FINAL REPORT-EXECUTIVE SUMMARYV1	15JE72	HB	006
MD	15MR72	MDC-E0558		TECHNICAL REPORT SYSTEM + ORBITER PART 2 VOL 1	15JE72	HB	007
MD	15MR72	MDC-E0558		TECHNICAL REPORT SYSTEM + BOOSTER PART 2 VOL 2	15JE72	HB	008
MD	15MR72	MDC-E0558		FINAL MASS PROPERTIES REPORT PART 4	15JE72	HB	009
MD	15MR72	MDC-E0558		DEVELOPMENT REQUIREMENTS PART 3	15JE72	HB	010
MD	15MR72	MDC-E0558		TECHNICAL REPORT-MMC ACTIVITY PART 2 VOL 3	15JE72	HB	011
NR	15MR72	MSC-03332		SS PHASE B FINAL REPORT-TECHNICAL SUM.ADD.A-BOOSTER	15JE72	HB	012
LC	15MR72	NAS826362		SPACE SHUTTLE CONCEPTS TECHNICAL REPORT VOL 2	15JE72	HB	013
MD	15MR72	MDC-E0558		EXECUTIVE SUMMARY PART 1	15JE72	HB	014
NR	15MR72	MSC-03333		SS PHASE B FINAL REPORT-MASS PROPERTIES STATUS REPORT	15JE72	HB	015
GR	15MR72	MSC-03824		SS PHASE B FINAL REPORT-TECHNICAL REPORT V2	15JE72	HB	016
NA	09FE72	EG13728		SPACE SHUTTLE GUIDANCE AND NAVIGATION REVIEW	15JE72	HB	017
BC	04JA72			STUDY OF MOTION SYSTEM REQ. FOR SIM. OF ADV. SPACECR.	15JE72	HB	018
NA	15MR72	MSC-06720		SOURCE DOCUMENTATION LIST VOL 2 CAT 2	15JE72	HB	019
NA		RFP		SPACE SHUTTLE PROGRAM REQUEST FOR PROPOSAL PHASE CD	15JE72	HB	020
NA	14JA72		A	SPACE SHUTTLE AVIONICS CONFIGURATION DEFINITION DATA	15JE72	HB	021
MM	OC71	MSC-05218		PREL. DES. OF SHUTTLE DOCKING AND CARGO HANDLING SYS.	15JE72	HB	022
NA	15MR72			DATA PKG FOR SHUTTLE TRAINING AIRCRAFT DEFINITION	15JE72	HB	023
NR	15MR72	MSC-03332		SS PHASE B FINAL REPORT-EXECUTIVE SUMMARY V1	15JE72	HB	024
NR	15MR72	MSC-03332		SS PHASE B FINAL REPORT-TECHNICAL SUMMARY V2	15JE72	HB	025
NA	15NV71	MSC-03690		SS ORBITER GN+C S/W FUNCT.REQ. VERTICAL FLIGHT OPNS.	15JE72	HB	026
NA	JA73	NHB8040.2		APOLLO CONFIG.MGT. MANUAL	07JL72	HB	027
NA	01DC71	MSC-04217	B	SHUTTLE GNC DESIGN EQNS VOL.1	15JE72	HB	028
NA	01DC71	MSC-04217	B	SS GN+C DESIGN EQUATIONS-PREFLIGHT THRU ORBIT INS. V2	15JE72	HB	029
NA	01DC71	MSC-04217	B	SS GN+C DESIGN EQUATIONS-ORBITAL OPERATIONS V3	15JE72	HB	030
NA	01DC71	MSC-04217	B	SHUTTLE GNC DESIGN EQUATIONS VOL 4 DEORBITAL ATM OPNS	15JE72	HB	031
NA	15JE72		B	PROGRAM PLAN C ULASKY	15JE72	HB	032
NA	15MR72	MSC-06720		SOURCE DOCUMENTATION LIST VOL 1 CAT 1	15JE72	HB	033
NA		INDEX		SPACE SHUTTLE DATA LIST	15JE72	HB	034
NR	12NV71	NAS910960		TECHNICAL REPORT PHASE B VOL 1	15JE72	HB	035
NR	12NV71	NAS910960		TECHNICAL REPORT PHASE B VOL 2	15JE72	HB	036
NR	25JE71	NAS910960		TECHNICAL SUMMARY ORBITER DEFINITION VOLUME 2 PART1	15JE72	HB	037
NR	25JE71	NAS910960		TECHNICAL SUMMARY ORBITER DEFINITION VOLUME 2 PART2	15JE72	HB	038
GE	12NV71	NAS911160		SPACE SHUTTLE LOW COST/RISK AVIONICS STUDY	15JE72	HB	039
GE	15DC71	NAS911160		SHUTTLE SYSTEMS EVALUATION ORBITER DATA VOLUME 3	15JE72	HB	040
NR	08MR72	NAS910960		SPACE SHUTTLE PHASE B FINAL AVIONICS REPORT	15JE72	HB	041
NA	21AP71	NAS826187		ENGINE DESIGN DEFINITION REPORT AVIONICS-PHASE CD	30JE72	HB	042
MD	01AP72	MDC-E0558		SIMULATION RESULTS REPORT	28JE72	HB	043
MD	30AP72	MDC-E0573		DISPLAYS + CONTROLS FUNCTIONAL REQUIREMENTS SPEC.	28JE72	HB	044

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NA	04AP72	MSC INDEX	MSC INFORMATION RETRIEVAL SYSTEM	27JE72	H	045
MD	01OC71	MDC-E0464	CREW INTERFACE DEFINITION STUDY PHASE 1	28JE72	H	046
AF	00AP66	FTCTR686	FACILITY DEFINITION STUDY FOR UNIV FLIGHT SIMUL/TRNR	15JE72	HB	047
MI	00JE72	E-2667	EVAL OF SYNC/ASYNC EXECUTIVE SYSTEM FOR SPACE SHUTTLE	05JL72	HB	048
NA	01MA71	MSC-02542	TYP.SHUTTLE MISSION PROFILES + ATT.TIMELINES V4	11JL72	H	049
NA	27AG71	T71-14939	REPRES. REENTRY MISSION PROF. FOR DELTA WING ORBITER	11JL72	H	050
NA	31JA72	NASW-2081	ECONOMIC ANALYSIS SHUTTLE SYSTEM VOL 2	11JL72	H	051
LC	15NV71	NAS826362	ALTERNATE CONCEPT + DEFINITION-SRM BOOSTERS PART 3	11JL72	H	052
LC	15NV71	NAS826362	ALTERNATE CONCEPT + DEFINITION-AVIONICS PART 4	11JL72	H	053
NA	20JE72	MSC-07034	FIRST VERTICAL FLIGHT TEST MISSION	14JL72	HB	054
NA	16JE72	MSC-07053	OPTIMUM SRM THRUST PROFILE-MINIMUM GLOW	14JL72	HB	055
NA	30MA72	MSC-07057	POST BLACK OUT GNC ANALYSIS OF ORBITER SPACE SHUTTLE	14JL72	HB	056
MD	15MR72	MDC-E0558	DESIGN DATA BOOK-PROGRAM AND SYSTEM BASELINE PARTS V1	14JL72	HB	057
MD	15MR72	MDC-E0558	DESIGN DATA BOOK-DRAWINGS VOL 2	14JL72	HB	058
MD	15MR72	MDC-E0558	DESIGN DATA BOOK-ORBITER AERO VOL 3	14JL72	HB	059
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NA	11JL72	470 ICD14	MAIN ENGINE AVIONICS ICD-ROCKETDYNE	20JL72	HB	061
NR	14JE72	AIAA71659	ROCKETDYNES SPACE SHUTTLE MAIN ENGINE	20JL72	H	062
NA	MA71	MSC-04400	RECOMMENDED SPACE SHUTTLE COORDINATE SYSTEMS STANDARD	26JL72	HB	063
LG	26FE71	MSC02553	ADVANCED S/W TECHNIQUES FOR SHUTTLE DATA MAN. SYSTEM	25JL72	HB	064
SK	30NV70	SKC-2000	AEROSPACE DIGITAL COMPUTER-SKC 2000	07JL72	HB	065
NA	05AP72	MSCLG7215	SOLID STATE TRANSUCER DEVELOPMENT%NEW HAND CONTROLL	26JL72	HB	066
NA	12MA72	MSC-07151	FLYING QUALITES REQUIREMENTS CLOSED LOOP FLY BY WIRE	26JL72	HB	067
NA	21DC70	A71-25530	SUPPLY + RESUPPLY OF STATIONS IN SYNCRONOUS ORBITS	25JL72	H	068
BA	15MR72	AIAA71313	INSTRUMENTAION REQUIRED FOR SHUTTLE MAINT + OPERATION	25JL72	H	069
NA	03AP72	MSC-06766	PERFORMANCE REQUIREMENTS-SHUTTLE FUNCTIONAL SIMULATOR	25JL72	H	070
NA	13JL72	CE2-72M86	MALFUNCTION STUDY (RELATIVE TO HFTS)	26JL72	HB	071
MD	30JE71	MDC-E0308	PHASE B TECHNICAL SUMMARY PART 11-1	07JL72	B	072
MD	30JE71	MDC-E0308	B TECHNICAL SUMMARY ORBITER PT11-2A	07JL72	B	073
MD	30JE71	MDC-E0308	B TECHNICAL SUMMARY ORBITER PT11-2B	07JL72	B	074
MD	30JE71	MDC-E0308	B TECH. SUMMARY BOOSTER PART 11-3	07JL72	B	075
MD	30JE71	MDC-E0308	B TECH. SUMMARY BOOSTER PT 11-3 APP	07JL72	B	076
NR	JL70	MSC-00706	SP.STA. C/D CREW TNG PLAN R DEFIN.	07JL72	B	077
NR	25JE71	MSC-03307	SHUTTLE B EXEC. SUMMARY VOL.1	07JL72	B	078
NR	25JE71	MSC-03308	PROGRAM MGT.PLAN FOR PHASE C/D	07JL72	B	079
NR	25JE71	MSC-03327	EXTERNAL H2 TANK STUDY SUMMARY VOL1	07JL72	B	080
NA	17DC70	MSC-03793	SHUTTLE ENG.SIMULATION SURVEY	07JL72	B	081
GE	06JL71	MSC-03809	ALTERNATE CONCEPTS-EXEC SUM PART 1	07JL72	B	082
GE	06JL71	MSC-03810	ALT.CNCPTS.TECH.SUM.SHUT.DEF. P2V1	07JL72	B	083
GE	06JL71	MSC-03811	ALT.CNCPTS.ENG DEV.PLAN-ORBITER V2	07JL72	B	084
NA		MSC-04240	PRELIM.MISSION PROFILE-DESC.+LAND	07JL72	B	085
NA	27AP71	MSC-04243	PRE.ENTRY TGT PLANNING-ORBITER	07JL72	B	086
NA	24AG70	17618H004 0	ENTRY CORRIDORS FOR HI L/D (TRW)	07JL72	B	087
NA	06AP72		FLIGHT PERS.COMP.+SIMULATOR RES-INF	07JL72	B	088
NA	08JE72	C.OLASKY	PROGRAM PLAN-PROCEDURES DEVELOPMENT	28JE72	HB	089
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NR			PRELIM NAR CONTROLS DISPLAY LAYOUT		B	092
SI	15JL72	SSPEMM31	SSPF DATA BOOK		B	093
NA	30AP71	MSC-04347	SHUTTLE TOUCHDOWN REQUIREMENTS		B	094

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AF	00MR72	HUMRR0772		TRANSFER OF INST TRAINING + SYNTH FLIGHT TRAINING SYS	28JL72	B	095
NA	30JE70	TMX-2101		FLIGHT TEST RESULTS FOR SPACE SHUTTLES (LIFT. BODIES)	26JL72	H	096
NA	11DC70	MSC-02542		TYPICAL SHUTTLE MISSION PROFILES + ATT TIME LINE VOL3	28JL72	HB	097
NA	07AG70	NAS910455		STUDY OF PERSONAL HYGIENE FOR FUTURE MANNED MISSIONS	28JL72	HB	098
NA	01OC71	MSC-C-005		GEN SPEC CONTRALS.FUNC DESIGN REQMTS MANNED SPACECRFT	28JL72	HB	099
NA	01NV71	MSC-D-007		GEN SPEC DISPLAYS.FUNC DESIGN REQMTS MANNED SPACECRFT	28JL72	HB	100
NA	30OC70	MSC-03779		HOUSEKEEPING CONCEPTS-WASTE CONTROL TASKS + SYS VOL 1	28JL72	HB	101
NA	17MR71	MSC-04062		ORBITER FLIGHT TECH + LANDING PT SUBORBIT ABORT CNTRL	28JL72	HB	102
NA	00FE71	NAS9-4045		MAN ROLE INTEG VEHICULAR INFORMATION MANAGEMENT SYS	28JL72	HB	103
NA	25JE71	MSC-03305		ICD FOR SPACE SHUTTLE SYSTEM	28JL72	HB	104
NA	27JL71	MSC-04711		ORBITER FLIGHT TECHNIQUES FOR FLYBACK ABORTS	28JL72	HB	105
NA	11NV71	MSC-05148		PAYLOAD CG ANALYSIS FOR SHUTTLE.SIDE-BY-SIDE LOADING	28JL72	HB	106
NA	10JA72	MSC-05812		PAYLOAD CG ANALYSIS FOR SHUTTLE.END-TO-END LOADING	28JL72	HB	107
NA	15DC71	MSCEG7143		PILOTED SIMUL STUDY-UNPOWERED CROSSWIND LANDINGS	28JL72	HB	108
NA	00JL71	NAS911140		CHECKOUT SYS SUMMARY REPORT/UNIV CONTROL-DISPLAY CONS	28JL72	HB	109
NA	00DC71	NAS912420		TIFS SIMUL OF SSV LANDING APPROACH-MONTHLY REPORT	28JL72	HB	110
NA	15DC71	NAS912218		DEV OF OPTIMUM SIMUL OF SPACE STATION COMM TECHNIQUE	28JL72	HB	111
NA	00DC71	NAS912200		SSV ENTRY SIMULATION	28JL72	HB	112
NA	00DC71	NAS910950		STUDY ANALYSIS REPORT OF SSV MANUAL DOCKING SIMULATOR	28JL72	HB	113
NA	28SE71	AD444403		AIRCRAFT FLIGHT TEST INSTR ANALYSIS FOR SSV	28JL72	HB	114
NA	00FE72	NAS912420		TIFS SIMUL OF SSV LANDING APPROACH-MONTHLY REPORT	28JL72	HB	115
NA	15DC71	NASW-2129		INTEG SPACE PROGRAM + VEHICLE SYS ANALYSIS-STUDY B	28JL72	HB	116
NA	00AG71	NASW-2129		INTEG OPERATIONS/PAYLOAD/FLEET ANALYSIS VOL 2 PAYLOAD	28JL72	HB	117
NA	00AG71	NASW-2129		INTEG OPERATIONS/PAYLOAD/FLEET ANALYSIS VOL 5 MISSION	28JL72	HB	118
NA	00AG71	NASW-2129		INTEG OPERATIONS/PAYLOAD/FLEET ANALYSIS VOL 3 EXEC SM	28JL72	HB	119
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NA	02JE71	NAS910960		SPACE SHUTTLE OPERATIONS REVIEW	28JL72	HB	121
NA	05JA71	NAS910960		SPACE STATION DOCKING/PAYLOAD XFER TRADE STUDY RESULT	28JL72	HB	122
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NA	10JA72	MSCEG72-5		PROJECT SPACE SHUTTLE-SSV ENTRY SIMULATION	28JL72	HB	125
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NA	25JE71	MSC-03310		SSV OPERATIONS PLAN FOR PHASE C/D VOL. 2 ORBITER	28JL72	HB	127
NA	00MA71	MSC-04411		SSV PAYLOAD HANDLING + DOCKING	28JL72	H	128
NA	19AP71	A71-36469		ORBITAL CARGO TRANSFER SYSTEM	28JL72	HB	129
NA	00JL71	NAS911946		SPACE STATION BUILDUP SIMULATION-FINAL REPORT	28JL72	HB	130
NA	10FE71	SSPD-27		SSV EVALUATION OF FOUR SIDESTICK CONTROLLERS ON SIMUL	28JL72	HB	131
NA	16MA72	MSC-04813	1	SSV PERFORMANCE CAPABILITIES-	01AG72	HB	132
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NA	00JE71	N70-40951	SPACE XPORTATION SYS TECH VOL 6 INTEGRATED ELEC/POWER	03AG72	H	145
NA	00JL72	DCPS-1	CREW PROCEDURES TASK DESCRIPTION-POST ABORT	03AG72	H	146
NR	04FE71	SV71-13	SSV CREW STATION REVIEW NO 2	03AG72	H	147
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NA	24MR72	MSC-06747	GNC S/W FUNCTIONAL REQ. HOR. FLIGHT OPERATIONS	07AG72	HB	152
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NA	31JL72	MSC-03690 C	SS ORBITER GNC S/W FUNCT. REQMNTS VERTICAL FLIGHT OPN	10AG72	HB	159
NA	27JE72	MSC-06900	SS BASELINE ACCOMODATIONS FOR PAYLOADS	10AG72	HB	160
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NR	00JL70	SSE4.1A17		SSE TRANSLATING NOZZLE-ORBITER SSME	14SP72	H	209
NR	00AG70	SSE4.1A24		SSE BASELINE ENGINE CONFIGURATION CHANGE	14SP72	H	210
NA	15MR72	13M15000	D	ORBITER VEHICLE/ENGINE 470K VACUUM ICD	14SP72	H	211
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NR	01JA72	NAS912046		APS PROPELLANT THERMAL CONDITIONER STUDY REPORT 7	14SP72	H	214
NR	01DC71	NAS912046		APS PROPELLANT THERMAL CONDITIONER STUDY REPORT 6	14SP72	H	215
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NA	21JF69	FHP-5-2		BLD NO 5 MISSION SIMULATION + TRAINING FACILITY	050C72	HB	245
				AIR TRAFFIC CONTROL SYS-DIGITAL SIMULATION FACILITY	050C72	HB	246
				A REAL TIME RADAR SIMUL USING APL DIGITAL COMP LINKS	050C72	HB	247
				A COMPARISON OF 3 TYPES OF MANUAL CONTROLS-3RD ORDER	050C72	HB	248
IN	FE72			INERTIAL SYS FUNCTIONAL + DESIGN REQ FOR ORBITER-R	050C72	HB	249
				REAL TIME SPACE VEHICLE + GSE SOFTWARE SIMULATOR-COO	050C72	HB	250
				TORQUE SENSITIVITY A-FUNCTION OF KNOB RADIUS + LOAD	050C72	B	251
MI	AG72	E-2708		ENERGY MANAGEMENT DURING SHUTTLE TRANSITION	050C72	HB	252
	AF72			SYSTEM 86 LIBRARY	050C72	HB	253
NA	JL72	MSC-07036		SIMULATION OF MANNED SPACE FLIGHT FOR CREW TRAINING	060C72	HB	254
SI	27SP72			PROGRAMMING ELEMENTS.SMS TRAINING-BURKE/VANBUCKEL/GRA	050C72	HB	255
MI	MR72			PROJECT INTREX	29SP72	HB	256
IB				AP 101	100C72		257
				VISUAL STUDY MCDONNELL-DOUGLAS	100C72		258
				COMPUTER STUDY MCDONNELL-DOUGLAS	100C72		259
				SHUTTLE DEVELOPMENT SCHEDULE	100C72		260
				LMS CREW TRAINING SCHEDULE	100C72		261
GE	AP72	NAS911948		REMOTE MANIPULATOR DYNAMIC SIMULATION	100C72		262
MA	AP72	CR123570		SHUTTLE PROP SYS ONBOARD CHECKOUT + MONITORING DEV	100C72		263
CC	08MA72	CR61378		COMPUTER SYS SIMULATION + ANALYSIS	100C72		264
IN	16FE72	N7221203		ADV SFTWR TECH FOR DATA MGMT SYS VOL 3-PROG LANGUAGE	100C72		265
IN	16FE72	N7221205		ADV SFTWR TECH FOR DATA MGMT SYS VOL 2-SSV EXEC SYS	100C72		266
IN	16JF71	N7221204		ADV SFTWR TECH FOR DATA MGMT SYS VOL 1-SSV SW STUDY	100C72		267
MS	07MA72	CR123569		FLIGHT PROGRAM LANGUAGE REQMT	100C72		268
SF	- 71			ATC FOR THE SEVENTIES PART 1	100C72		269
SF	- 71			ATC FOR THE SEVENTIES PART 2	100C72		270
SF	- 71			ATC FOR THE SEVENTIES PART 3	100C72		271
AI	08MA71	A71-30381		PROG TECH FOR REAL TIME SYS FORM EXPERIENCE W EXPERMT	100C72		272
NA	DE70	TN-D-6068		DESIGN E OPER CHAR OF CENTRAL ONLINE DATA PROC-LANGLY	100C72		273
TN	AF71	TSC-FAA71		CONCEPTUAL NETWORK MODEL OF AIR TRANS SYS	100C72		274
MA	JA71	CR118310		VIRTUAL MEMORY SYS DESIGN	100C72		275
RA	JA71	CR118866		EXPERIENCE WITH EXTENDABLE COMPUTER SYS SIMULATOR	100C72		276
MT	MR71	MTR-1995		AIRCRAFT MOCKUP COMPUTER PROGRAM SPECIFICATIONS	100C72		277
AI	05MR68			NOMOGRAM FOR AIRCRAFT RUDDER PEDAL DESIGN	100C72		278
AI	05MR69			OPTIMUM KNOB DIAMETER	100C72		279
AI	05MR69			DESIREABLE DIMENSIONS FOR CONCENTRIC CONTROLS	100C72		280
MI	JF69	CR106370		MANUAL CONTROL OF UNSTABLE VEHICLES-KINESTHETIC CUES	100C72		281
RA	AU69	RM-6027		ONLINE DEBUGGER FOR G5360 ASSEMBLY LANGUAGE PROGRAMS	100C72		282
MA	JA70	CR110445		METHOD FOR UNIFIED HARDWARE-SOFTWARE DESIGN	100C72		283

Ref.
Key

5.0 External Interfaces

The shuttle vehicle, because of its objectives and design, has many interfaces with modules external to itself. It is necessary to be familiar with these interfaces to allow the design of a simulation interface and enhance the coordination necessary in such a design.

This section has been written to place in one area all the interfaces that must be considered. Figure 5.1-1 shows the interfaces of the real world system.

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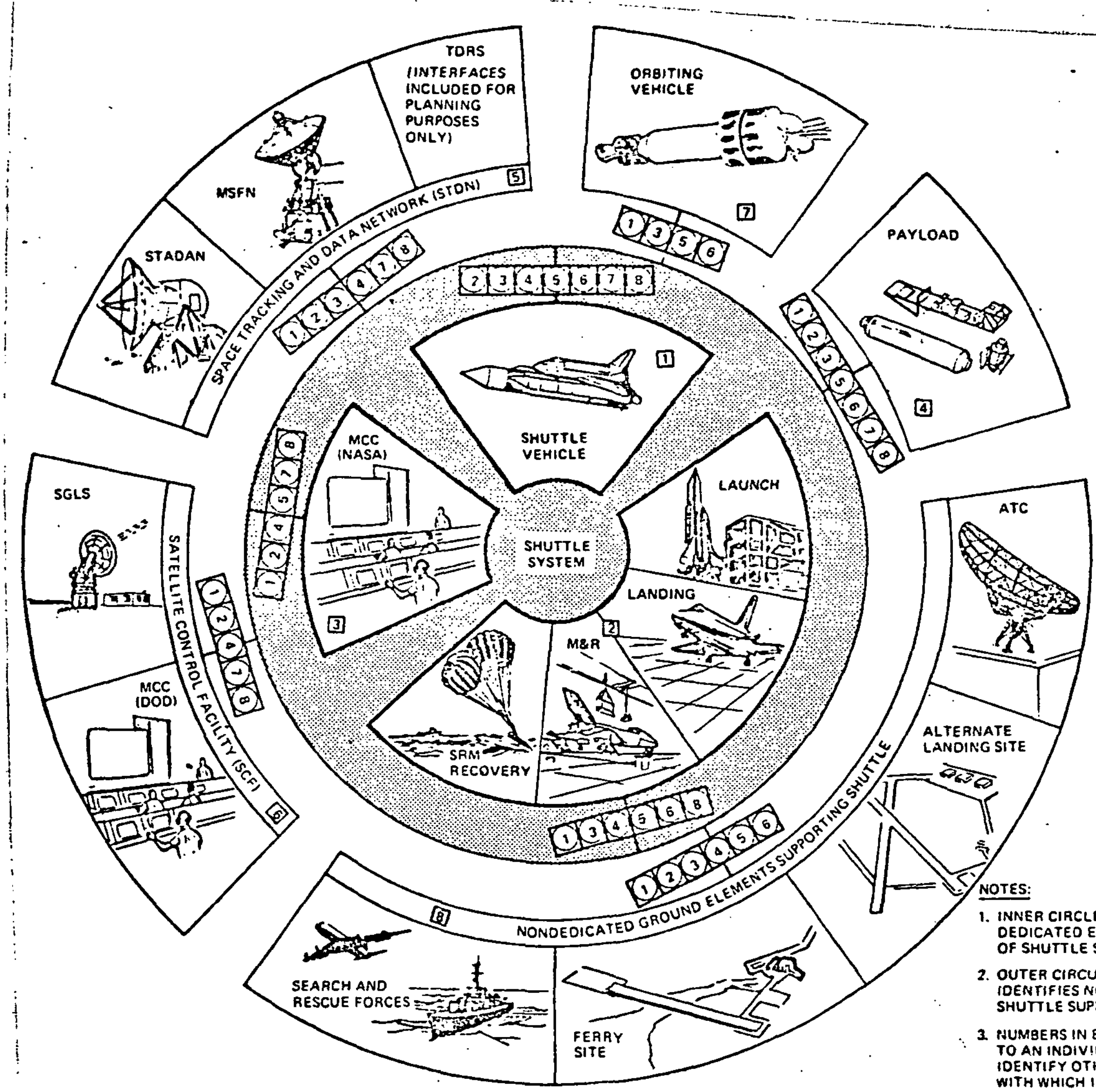

NOTES:
1. INNER CIRCLE COMPRISES DEDICATED ELEMENTS (1-3) OF SHUTTLE SYSTEM.
2. OUTER CIRCUMFERENCE IDENTIFIES NONDEDICATED SHUTTLE SUPPORT ELEMENTS (4-8).
3. NUMBERS IN BOXES ADJACENT TO AN INDIVIDUAL ELEMENT IDENTIFY OTHER ELEMENTS WITH WHICH IT INTERFACES.

Figure 5.1-1 Shuttle System Interfaces

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The interfaces shown indicate, for example, that the orbiting

166 P.2-133 vehicle (Unit 7) has four interfaces. These are Unit 1 - Shuttle Vehicle, Unit 3 - MCC NASA, Unit 5 - STDN, and Unit 6 - SCF only. It does not interface with units 2, 4, 7, or 8.

Prior to Launch, there are other interfaces involved in each area. For example, Unit 2 may be broken down into the general areas as seen in Figure 5.1-2.

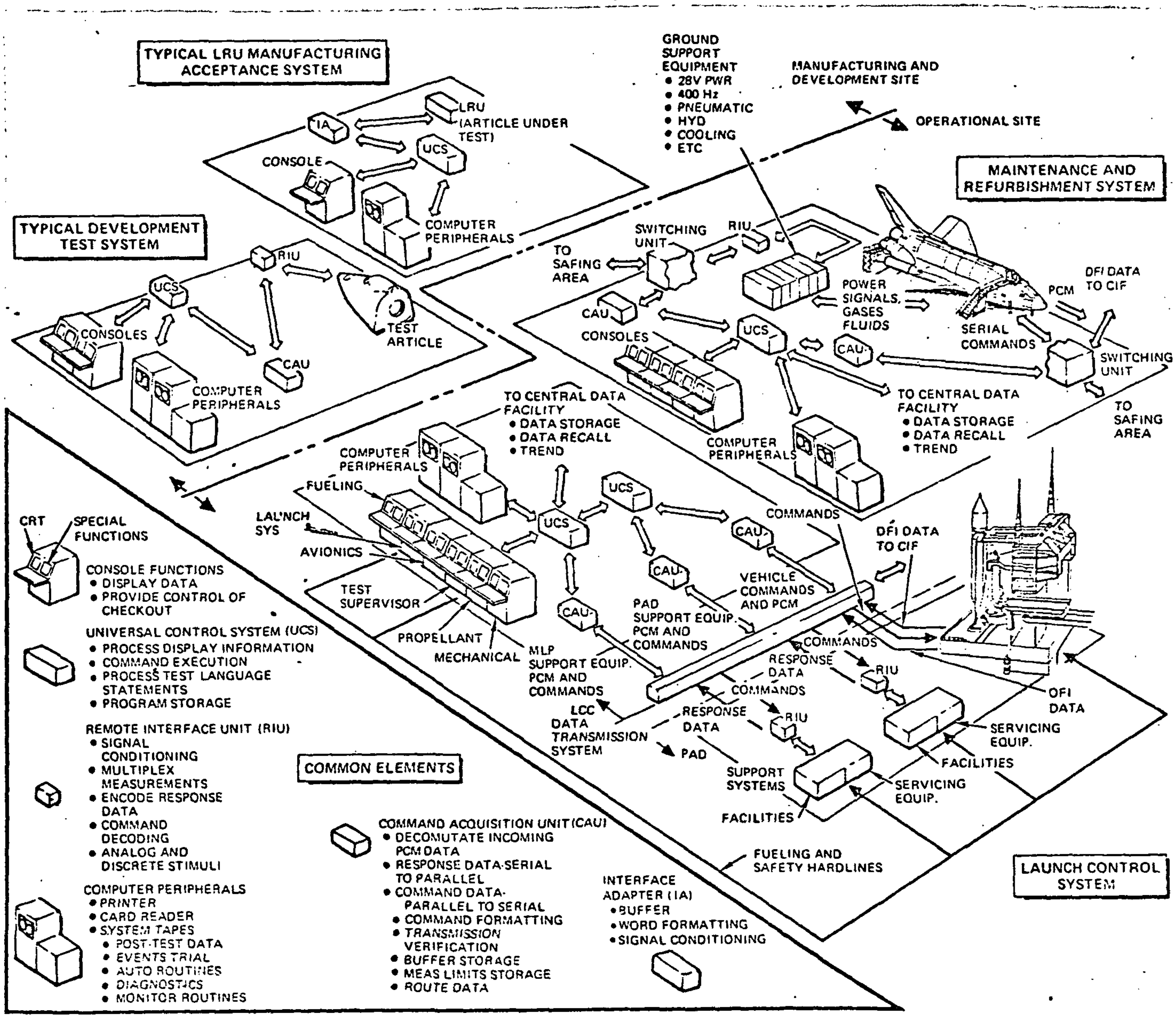

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Figure 5.1-2 Modular Buildup of GCDC System for LRU Through Launch

Ref. Key

The Ground Checkout Display and Control GCDC system is a computer-
166 controlled checkout system which will receive, decommutate, process, and display the orbiter operational flight instrumentation data and provide commands to the orbiter by way of a serial digital hardline to the onboard command/decoder which in turn will route hardwire commands to the vehicle subsystems. The GCDC system will also provide serial digital commands to the remotely controlled GSE and monitor the pulse code modulation (PCM) data stream containing GSE measurements. The serial digital command and response links will be supplemented by dedicated command and response hardlines for safe operation during contingency situations. Failure detection capabilities will be designed into the GCDC system. Some of these will be power failure detection, input-output parity checks, illegal operation and address checks, and command verification checks. The vehicle development flight instrumentation (DFI) data bit stream will be hardwired to a telemetry ground station during ground checkout (the central instrumentation facility at KSC) for recording and analysis. Appropriate summary data will be sent to the GCDC system operator.

The GCDC system supplements the orbiter onboard capability for orbiter manufacturing final assembly checkout, malfunction isolation in maintenance and repair, and control and monitor of prelaunch and launch operations. The elements of the GCDC system are display and control consoles, universal control system, command acquisition unit, and remote interface unit. See Figure 5.1-2 for definition of how these system elements are used as building blocks from LRU checkout through the GCDC launch system.

5.1 Display and Control (D&C) Consoles

The D&C consoles provide the man-machine interface of the GCDC system. Color CRT's will be used for the D&C console baseline. The

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keyboard is the primary operator interface with the universal control system. This keyboard is used to call up instructions and data to be displayed on the CRT and initiate test routines. In addition, capability is provided on the special function panels to command preselected functions by depressing a function switch, thereby issuing a computer or hardline command via a single operation action.

5.2 Universal Control System (UCS)

The universal control system contains the checkout processor which
166 controls the checkout operation. This processor interfaces with the D&C consoles and peripheral equipment, i.e., printer and magnetic tape units, via input-output modules contained in the universal control system. This system also contains a disk memory module used for storage of automatic test routines, and it interfaces with the command acquisition units. Commands to the vehicle of GSE are initiated from the D&C console keyboard and are processed by the universal control system before transmission to the command acquisition units.

5.3 Command Acquisition Unit (CAU)

The command acquisition unit receives measurements in a PCM format
166 from the vehicle and support equipment which are limit-checked against programmable limits stored in the unit's disk memory module. The measurement data are then transmitted to the universal control system. The command acquisition unit receives commands from the system and reformats the command into a serial format, which includes verification information, and transmits the commands to the vehicle and GSE. Verification of receipt of command is transmitted back to the unit from the vehicle and GSE to insure that the command was properly received.

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5.4 Remote Interface Unit (RIU)

The remote interface unit provides the command and measurement
166 interface between the command acquisition unit and the GSE or facility equipment being controlled and monitored. The remote interface unit receives serial command data from the command acquisition unit, transmits verification data back to it, and then issues commands to the controlled equipment. The remote interface unit also accepts measurement data from the monitored equipment, and then formats and sends the data back to the command acquisition unit in PCM serial format.

The GCDC system interfaces with an off-line computer center known as the central data facility, which stores the system test data and provides procedural information and post-test data to the system.

5.5 Shuttle Vehicle Systems Interface

Table 5.1-1 lists the modules with which the shuttle might be interfaced. Associated with each of the modules listed in the left hand column is a second column of paragraph numbers of this document which contain information pertaining to the basic module and its interface with the shuttle vehicle. These interfaces with the basic module are then further broken into one of three types; electrical, mechanical, or data. If the interface falls into the data category, references to the data type, the parameters, the data rate, format and response are listed where available.

The interface between the shuttle vehicle and the Mission Control Center are not direct in that the data is routed through the ground station network. This interface is therefore defined by the other modules listed in Table 5.1-1.

ITEM (MODULES)	GENERAL DESCRIPTION	ELEC	MECH	DATA: TYPE	PARAMETERS	REFERENCE PARAGRAPHS: RATES	FORMAT	RESPONSE
	Fig. 4.10.2-1			L-Band Radar	Location Altitude	N/A	N/A	N/A
	Fig. 4.10.2-2			UHF/VHF ILS	Azimuth Glide Path	N/A	N/A	N/A
	4.10.2 4.10			VHF Voice		N/A	N/A	N/A
LANDING &	4.10.3			UHF Voice		N/A	N/A	N/A
APPROACH CONTROL	4.10.5 Fig. 4.10.2-1			TACAN	Azimuth	4.10.5	4.10.5	4.10.5
					Distance	4.10.5	4.10.5	4.10.5
FAA	4.10.7			ATC Transponder	Altitude	4.10.7	N/A	N/A
&	4.10.8 2.1.1.8			ILS	Direction Glideslope	N/A N/A	N/A N/A	N/A N/A
GCA	4.10.9			GCA	Cross Track Distance Height	N/A	N/A	N/A
	4.10.10			FAA Radar	Range Azimuth	N/A	N/A	N/A

TABLE 5.1-1 SHUTTLE VEHICLE SYSTEMS INTERFACE

ITEM (MODULES)	GENERAL DESCRIPTION	ELEC	MECH	DATA: TYPE	PARAMETERS	REFERENCE PARAGRAPHS: RATES	FORMAT	RESPONSE
LANDING & APPROACH CONTROL (CONT'D)	4.10.11			PRS	Range	4.10.11	N/A	4.10.11
					Range Rate	4.10.11	N/A	4.10.11
					Range	4.10.12	N/A	4.10.12
	4.10.12			MLS	Azimuth	4.10.12	N/A	4.10.12
					Elevation	4.10.12	N/A	4.10.12

ITEM (MODULES)	GENERAL DESCRIPTION	ELEC	MECH	DATA: TYPE	REFERENCE PARAGRAPHS: PARAMETERS	RATES	FORMAT	RESPONSE
	2.1.1.1.1							
	2.1.1.5.3.1							
LAUNCH	2.1.1.5.4.1							
CONTROL	4.11.3							
WTR				DFI Telemetry	Figure 4.11-1	4.11.2		
&	4.11							
ETR				OFI Telemetry	Figure 4.11-1	4.11.2		

ITEM (MODULES)	GENERAL DESCRIPTION	ELEC	MECH	DATA: TYPE	REFERENCE PARAGRAPHS: PARAMETERS	RATES	FORMAT	RESPONSE
	4.10							
	4.10.1							
	4.10.1.1				Voice			
	4.10.1.2				Telemetry	4.10.1.2	TBD	TBD
	4.10.1.3				Commands	4.10.1.3/4.10.2-1	TBD	TBD
SGLS	4.10.1.4				Video	N/A	N/A	N/A
&	4.10.1.5				Wide Band Data	TBD	TBD	TBD
STDN	4.10.1.6				Tracking	TBD	N/A	TBD
	4.10.2			VHF	Voice	N/A	N/A	N/A
					Data	4.10.2	TBD	TBD
						Fig. 4.10.2-1	TBD	TBD

ITEM (MODULES)	GENERAL DESCRIPTION	ELEC	MECH	DATA TYPE	REFERENCE PARAGRAPHS PARAMETERS	RATES	FORMAT	RESPONSE
	4.11			DFI	Table 4.11-1	Table 4.11-2	TBD	TBD
				OFI	Table 4.11-1	Table 4.11-2	TBD	TBD
	4.11.2			Telemetry				
SGLS	2.1.1.5.1.1			DFI				
&	2.1.1.5.1.1.1							
STDN	2.1.1.8.4.1			Tracking				
(Cont'd)	4.3.4			Engine Telemetry	Table 4.3.4-1			
	4.3.4.1			Alternate Engine Parameters	Table 4.3.4.4-1			

ITEM (MODULES)	GENERAL DESCRIPTION	ELEC	MECH	DATA TYPE	REFERENCE PARAGRAPHS PARAMETERS	RATES	FORMAT	RESPONSE
EVA	4.10			VHF	Voice Telemetry	N/A TBD	N/A TBD	N/A TBD
DETACHED PAYLOAD	4.10 4.13.4			VHF	Voice Telemetry Commands	N/A Figure 4.10.2-1 4.10.2	N/A TBD TBD	N/A TBD TBD
					L-Band	Range		
SGLS DETACHED PAYLOAD	4.10 4.13.4			Secure S-Band	Voice Data Command	N/A TBD TBD	N/A TBD TBD	N/A TBD TBD
ATTACHED PAYLOAD	4.10 4.13.4	TBD	TBD	VHF	Voice Data Command	N/A 4.13.4 4.13.4	N/A TBD TBD	N/A TBD TBD
				S-Band	Wide Band Data	TBD	TBD	TBD

6.0 Crew Procedures

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In establishing the requirements for the Shuttle Mission Simulator, it is necessary to examine the mission objectives and the tasks required of the crew in order to accomplish those objectives. Task requirements were based on studies conducted during Phase B. Because of the sparsity of data available at the time of this study, it was impossible to develop comprehensive crew procedures. With this restraint, the study was limited to defining the tasks required of the crew. However,this limitation will not detract from the objective of providing a baseline from which simulator requirements can be determined.

For the purpose of this study, the crew is composed of a Commander, Pilot, Mission Specialist(s), and Payload Specialist(s). The following is a brief description of the duties of the crew.

(1) Commander: The Commander is in charge of the flight and responsible for the overall space vehicle, personnel, payload flight operations, and vehicle safety. As Commander, he is proficient in all phases of vehicle flight, payload manipulation, docking and subsystem command, control, and monitor operations. He is knowledgable of the payload(s) and payload systems as they relate to flight operations, communications requirements, data handling, and vehicle safety.

(2) Pilot: The Pilot is second in command. His duties are essentially the same as the Commander.

(3) Mission Specialist: The Mission Specialist is responsible for interfacing the payload and orbiter operations, as well as management of payload operations. He is proficient in vehicle and payload subsystems, flight operations, and payload communications.

(4) Payload Specialist: The Payload Specialist is responsible for the applications, technology, and science payload and payload instrument operations. He has a comprehensive knowledge of the payload instrument, operations, requirements, objectives and supporting equipment.

The size of the crew is determined by the mission objectives and could vary from mission to mission. The basic crew consists of Commander and Pilot. The number of Mission Specialists and Payload Specialists assigned to a crew depends upon the mission requirements. Many missions, especially in the early stages of the program, will be flown with a basic crew.

6.1 Mission Objectives

46 pg.3-2, 3-3 Reference 46 outlines the following types of missions as being representative of those which will be flown during the Space Shuttle Program:

(1) Space Station Resupply

(2) Propellant Delivery

(3) Propulsive Stage Delivery

(4) Orbit-to-Orbit Shuttle Delivery and Retrieve

(5) Satellite Placement

(6) Shuttle Retrieval

(7) Satellite Placement and Retrieval

(8) Short Duration Orbital

(9) Rescue

The study further analyzed the objectives of each mission and concluded that any of the space shuttle missions could be accomplished using combinations of the following major flight operations:

(1) Ascent

(2) Rendezvous

(3) Orbit

(4) Payload

(5) Return

(6) Ferry

(7) Abort

46 pg.3-1- 3-9 Each major flight operation is comprised of a series of dependent phases. The following paragraphs present a resume of the objectives of each phase.

6.1.1 Ascent

During this flight operation, the orbiter is inserted

into initial orbit - nominal 50 x 100 NM. The ascent portion of the mission can be divided into four phases: Preflight, Mated Flight, Separation and Orbit Insertion.

(1) Preflight Phase: The primary objective is to prepare the vehicle for flight; the computers are loaded, external alignment and calibration performed, final targeting performed, mission timeline verified and the vehicle configured for launch.

(2) Mated Flight Phase: During this phase, the booster carries the orbiter to the desired separation conditions. Systems operation is monitored, and powered flight navigation is performed.

(3) Separation Phase: The booster and orbiter are separated during this phase. The booster separation is commanded and systems operation is monitored and controlled.

(4) Orbit Insertion Phase: The objective of this phase is for the orbiter to continue its flight and insert into orbit. The orbit main engines provide the primary thrust. Powered flight naviation is continued and insertion phase guidance is monitored.

6.1.2 Rendezvous

The primary mission objective during this operational sequence is to fly from insertion to a co-orbit condition with another orbital vehicle. The rendezvous sequence is divided

into periods of coasting and powered flight. During coast, the orbit is non-thrusting. Navigation operations are performed during coast periods initially using horizon sensor measurements, and line-of-sight range and angle measurements later in the rendezvous mode. The platform alignments are performed and tested against sightings and the spacecraft is maneuvered to the desired attitudes for performing the next maneuver. During long coasting periods, the guidance system may be powered down to a standby mode. During powered flight, the orbiter is thrusted using the OMS or RCS engines. Thrust vector control and attitude control are provided by the orbital powered flight guidance and control autopilot. The navigation incorporates acceleration measurement during powered flight. Rendezvous is divided into four phases: Orbital Adjustment, Coelliptic, Terminal and Station Keeping.

(1) Orbital Adjustment Phase: The objective in this phase is to correct the relative position of the orbiter with the rendezvous target. The catch-up - or dwell, if rendezvous is from above - can vary from zero to 18 hours depending on the initial phasing at insertion. Several maneuvers can be made, usually horizontal in plane or nominal catch-up. The purpose of these maneuvers is to place the orbiter in a favorable position with respect to the target for performing the relative phase maneuvers. Navigation is corrected using

horizon sensor measurements.

(2) Coelliptic Phase: In the coelliptic phase, the requirement is to place the orbiter at the desired terminal condition prior to initiating an intercept trajectory. Navigation is accomplished through relative measurements. Maneuvers during this phase are corrective combinations which adjust the orbit to meet the lighting and relative motion requirements in the terminal phase and to remove GNC errors.

(3) Terminal Phase: During this phase, the orbiter is placed on an intercept trajectory with the target, and braking is performed to achieve a station-keeping condition. Navigation is corrected with relative measurements, and maneuvers are generally relative to the line-of-sight.

(4) Station Keeping Phase: In this phase, the relative position of the orbiter is maintained in the near vicinity of the target vehicle.

6.1.3 Orbit

The purpose of this operational sequence is to provide flexibility for performing orbital changes not necessarily connected with rendezvous. The particular operations for a mission depend upon the desired final orbit. Thus, a sequence could be generated which would range from one or two Hohmann transfers, if orbit size and shape are the only controlling parameters, to a "phantom" rendezvous sequence if perigee

location and time of perigee passage, or mode crossing are also to be controlled. As with the rendezvous sequence, a sequence of orbital operations would be divided into periods of coasting flight and powered flight. Based on the various mission objectives, the orbit sequence can have the following maneuvers:

(1) Hohmann Transfer Maneuvers: The objective of this maneuver is to perform a series of in-plane maneuvers - at apogee or perigee if the orbit is elliptical - designed to satisfy final orbit parameters. By controlling lift-off time and launch azimuth, many missions can be accomplished entirely within this capability.

(2) Out-of-Plane Maneuvers: This maneuver is employed to adjust in-plane and/or out-of-plane dispersions with one corrective maneuver. Because of high ΔV requirements, this phase is avoided, if possible, except for small adjustments.

6.1.4 Payload Operations

The purpose of this operation is to guide and control the orbiter to meet payload handling requirements. Depending on the mission, any or all of the following maneuvers could be encountered:

(1) Docking: The objective of this maneuver is to move from a station-keeping mode to a docking conditions with the rendezvous target. During docking, relative attitude and

rates as well as range and range rates are controlled parameters. Docking is performed manually.

(2) Undocking: In the undocking maneuver, the shuttle vehicle is moved from the docked condition.

(3) Payload Deploy/Retrieve: During this operation, the objective is to perform the necessary maneuvers while deploying, retrieving or otherwise handling payloads.

6.1.5 Return

The objective of this operational sequence is to return the orbiter from orbit to a preselected landing sight. The sequence includes orbital coasting and powered flight, as well as hypersonic, supersonic, and subsonic aerodynamic flight. The sequence is divided into four phases: Deorbit, Entry, Terminal Area and Final Approach.

(1) Deorbit Phase: The primary objective of this phase is to select a landing site and perform the deorbit maneuver. Platform alignment and navigation are required during this phase.

(2) Entry Phase: During this phase, preparations are made for entry interface. Final platform alignments and navigation is performed. The orbiter is configured for entry and rotated to entry attitude. When accomplished, the orbiter angle of attack and bank angle are controlled to avoid temperature, g-load and skip-out constraints. During this period, all

optical hatches are closed and radio blackout prevents measurement for correcting the propagation of navigation errors.

(3) Terminal Area Phase: The orbiter energy level is controlled during this phase to achieve the desired final approach conditions. Included in this phase is the transition maneuver during which the vehicle is maneuvered from the back-side to the front side of the L/D curve. After transition, energy dissipation is controlled by flying along a preselected path from which the vehicle can be steered easily onto the final approach. Navigation during this phase is by ground-based radio aids.

(4) Final Approach Phase: In this phase, the vehicle is controlled and guided to the touchdown point. Final approach is initiated along a steep glideslope - nominal 13 degrees - until intercept of the conventional ILS glideslope at approximately 800 feet. The ILS glideslope is then flown to touchdown.

6.1.6 Ferry Operations

During ferry operations, the vehicle is flown from one airport to another. This operation is similar to those involved in flying conventional aircraft. Ferry operations can be divided into five phases: Preflight, Takeoff, Cruise, Inflight Refueling, Descent and Landing.

REF KEY

(1) Preflight Phase: In this phase, the primary objective is to prepare for flight. The cruise route is selected and the vehicle is checked out for flight.

(2) Takeoff Phase: During this phase, the vehicle becomes airborne, climbs to cruise altitude and is configured for cruise. This is a manual operation.

(3) Cruise Phase: The vehicle is guided to the terminal area during this phase. Navigation is accomplished using VOR/DME radio aids and powered flight inertial navigation. Autopilot modes include attitude hold, heading hold, VOR and area navigation.

(4) Inflight Refueling: In this phase, the vehicle is maneuvered into a station-keeping position with the tanker aircraft. This position is maintained until the vehicle onloads the required amount of fuel.

(5) Descent and Landing: The primary objective in this phase is to land the vehicle at the terminal airport.

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6.1.7 Abort Operations

The primary objective is to interrupt the normal sequence where the abort situation occurs and carry the abort to a point where a nominal sequence can be reentered. Because on-orbit or descent/return aborts can be handled in the nominal sequence, abort operations are primarily for ascent aborts. Abort operations are identified with the following:

(1) Prelaunch: The prelaunch mode includes the period from crew and passenger boarding to launch commit. Crew and passengers egress to the launch tower platform and then to the blast room.

(2) Abort SRM (Launch Commit to 30 seconds): In abort during the first 30 seconds of flight, the orbiter is separated from the tank and SRM's. A separate propulsion system (ASRM) on the orbiter facilitates safe separation and return to the landing site. OMS propellant and the expended ASRM's are jettisoned prior to landing.

(3) Orbiter Glide (30 seconds to 86 seconds): The abort mode during this time interval is orbiter separation, without thrust augmentation, and glide return to the landing site.

(4) Orbiter Powered Return (86 seconds to 300 seconds): After 86 seconds, the orbiter returns to earth by means of a powered maneuver with the orbiter main engines. The return-to-site maneuver after SRM separation is achieved by orienting the orbiter thrust to decelerate the ascent velocity and fly back to the landing site.

(5) Orbiter Once-Around Abort (300 seconds to 440 seconds): For loss of thrust from a single main engine during this time interval, the abort mode is once around to the landing site. It utilizes OMS, RCS, and main

engine emergency power to compensate for loss from a single main engine.

(6) Orbiter Abort to Orbit (440 seconds to 551 seconds): If loss of thrust from a single engine occurs after 440 seconds of flight, the orbiter continues to orbit. Subsequent deorbit is accomplished using OMS propellant. Software requirements are essentially the same for a nominal mission.

During the abort phase, the crew would monitor the software programs dedicated to the abort. The programs would be monitored to a point where a nominal sequence can be reentered, and the mission continued from that point.

46 pg.3-10, 3-11

6.2 Requirements for Crew Participation

The display and control design requirements for the space shuttle in which both aircraft and spacecraft modes of operation are integrated necessitates a well organized method of on-board mission control and subsystem management. The on-board system will perform routine or pre-selected functions, automatically leaving the crew free to provide the decision-making functions and to perform certain special mechanical tasks. In this role, the crew will act as a system supervisor, sequence initiator and provide hardware/software back-up. Crew participation will comprise the following functions:

(1) Evaluation of mission sequence and mission status in real-time flight conditions.

(2) Specification of certain data, constraints, or performance options.

(3) Initiation of mission sequences and unique operations with the flight system and control of the mode of performance.

(4) Evaluation of the flight system and the capability of the flight system to perform.

(5) Determine what flight operation to perform and the manner of execution.

(6) Initiation and discontinuation of flight operations, phases, and tasks which are pertinent to the control of the flight system and the performance of the mission.

(7) Selection of the system interface with sensor components and the modes of subsystem operation.

(8) Recognition of pattern of degraded performance and logical fault isolation.

6.3 Task Requirements

6.3.1 Commander and Pilot

Based on data contained in Reference 46, the following is an outline of the task requirements of the Commander and Pilot. The outline does not designate the tasks by crew member since both crew members are expected to be equally

proficient. The outline is categorized by the phases which occur during the major flight operations as outlined in paragraph 6.1.

The payload handling tasks are based on Phase B studies (Reference 22) and data on the payload station contained in Reference 166. The task analysis was performed for the capture docking and transfer tasks since these tasks include the majority of the subfunctions of each of the other operational sequences. While the configuration of the payload handling console has not been definitized at this time, the one studied provides a baseline for determining the task requirements.

46 pg.31-32

6.3.1.1 Mission Sequence: Ascent

6.3.1.1.1 Prelaunch Phase

6.3.1.1.1.1 Control Functions

(1) Monitor autopilot modes

(a) auto rate

(b) attitude hold

(c) bank control

(d) attack control

(e) altitude hold

(f) VOR, GS, LOC hold

(g) heading hold

(h) area navigation

(i) auto land

(2) Management and control of attitude management mode

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(d) bank condition

(e) flight path angle condition

(f) nose wheel steering

(g) rate condition

(3) Management, monitor and control of attitude rates

(a) high-low

(4) Monitor and control of aero surface position indicator

(5) Control, control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) translation hand controller

(e) rotation hand controller select

(f) translation controller select

(g) rotation controller system

(h) translation controller system

(i) FDI reference

(j) FDI select

6.3.1.1.1.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, command and analysis of IMU alignment

(a) prelaunch

(4) Management, monitor, control and analysis of targeting elements

(a) velocity magnitude

(b) radial velocity

(c) out of plane velocity

(d) range

(e) position coordinates

(f) target ephemeris

(g) rendezvous technique

(h) time- rendezvous or landing

(5) Management, monitor, command, control and analysis of time to go elements

(a) liftoff

6.3.1.1.1.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion system

(g) payload

6.3.1.1.2 Mated Flight Phase

6.3.1.1.2.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude errors

(4) Monitor and control ΔV

(5) Monitor and control acceleration

(6) Monitor and control thrust level

(7) Monitor and control angular displacement

(a) angle of attack

(8) Monitor autopilot modes

(a) auto rate

6.3.1.1.2.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of speed and vertical speed

(a) IAS and mach no.

(b) rate of climb

(4) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(e) flight path angle

(5) Management, monitor, control and analysis of composite data and prediction elements

(a) altitude-velocity

(b) ground tracks

(6) Management, monitor, command analysis of time-to-go element

(a) separation

(7) Management, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) ΔV required

(d) ΔV to go

6.3.1.1.2.3 <u>Systems Monitoring Function</u>

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.1.3 <u>Separation Phase</u>

6.3.1.1.3.1 <u>Control Functions</u>

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control Δ V

(6) Monitor and control acceleration

(7) Monitor and control thrust level

(8) Monitor and control angular displacement

(a) angle of attack

(9) Monitor autopilot modes

(a) auto rate

(10) Management and control of attitude manual mode

(a) rate condition

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.1.3.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(4) Management, monitor, control of targeting elements

(a) velocity magnitude

(b) radial velocity

(c) out of plane velocity

(d) range

(e) position coordinates

(5) Management, monitor, control and analysis of composite data and prediction elements

(a) altitude-velocity

(b) ground tracks

(6) Management, monitor, control and analysis of time-to-go element

(a) main engine start/stop

(7) Monitor, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) ΔV required

(d) ΔV to go

6.3.1.1.3.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.1.4 Orbit Insertion Phase

6.3.1.1.4.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV

(6) Monitor and control acceleration

(7) Monitor and control thrust level

(8) Monitor and control angular displacement

(a) angle of attack

(9) Monitor autopilot modes

(a) auto rate

(10) Management and control of attitude manual mode

(a) rate condition

(11) Monitor and control, control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.1.4.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(4) Management, monitor, control and analysis of targeting elements

(a) velocity magnitude

(b) radial velocity

(c) out-of-plane velocity

(d) range

(e) position coordinates

(5) Management, monitor, command and analysis of composite data and prediction element

(a) altitude-velocity

(6) Management, monitor, command and analysis of time-to-go element

(a) main engines start/stop

(7) Monitor, control and analysis of derived data elements

(a) attitude rate

(b) angle of attack

(c) ΔV required

(d) ΔV to go

6.3.1.1.4.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.2 Mission Sequence: Rendezvous

6.3.1.2.1 Catch-Up Phase

6.3.1.2.1.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LV)

(6) Monitor and control acceleration

(7) Monitor and control thrust level (OMS)

(8) Monitor and control auto pilot modes

(a) attitude hold

(9) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotational hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.2.1.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command of IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevation and declination)

(6) Management, monitor and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of targeting elements

(a) target ephemeris

(b) time of rendezvous

(8) Management, monitor, control and analysis of composite data and prediction element

(a) target relative

(9) Management, monitor, command and analysis of time-to-go elements

(a) OMS engines start/stop

(b) attitude start/stop

(10) Monitor, control and analysis of derived data elements

(a) ΔV required

(b) ΔV to go

6.3.1.2.1.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.2.2 Relative Phase

6.3.1.2.2.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LV)

(6) Monitor and control acceleration

(7) Monitor and control thrust level (OMS)

(8) Monitor autopilot modes

(a) attitude hold

(9) Control attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.2.2.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, control and analysis of S-band ranging (range to target)

(6) Monitor, command and analysis of star tracker (star elevation and declination)

(7) Management, monitor and analysis of trajectory element

(a) orbital parameters

(8) Management, monitor control and analysis of targeting elements

(a) target ephemeris

(b) time of rendezvous

(9) Management, monitor, control and analysis of composite data and prediction element

(a) target relative

(10) Management, monitor, command and analysis of time-to-go elements

(a) OMS engines start/stop

(b) attitude start/stop

(11) Monitor, control and analysis of derived data elements

(a) relative range rate

(b) LOS rates

(c) ΔV required

(d) ΔV to go

6.3.1.2.2.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.2.3 Terminal Phase

6.3.1.2.3.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LV)

(6) Monitor and control ΔV (LOS)

(7) Monitor and control acceleration

(8) Monitor and control thrust level (OMS)

(9) Monitor autopilot modes

(a) attitude hold

(10) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(11) Management, monitor and control of attitude rates

(a) high-low

(12) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.2.3.2 <u>Navigation & Guidance Functions</u>

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of IMU alignment

(a) course alignment

(4) Monitor, and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, control and analysis of S-band ranging (range to target)

(6) Monitor, control and analysis of star tracker (star elevation and declination)

(7) Management, monitor and analysis of trajectory element

(a) orbital parameters

(8) Management, monitor, control and analysis of targeting elements

(a) target ephemeris

(b) time of rendezvous

(9) Management, monitor, control and analysis of composite data and prediction element

(a) target relative

(10) Management, monitor, command and analysis of time-to-go elements

(a) OMS engines start/stop

(b) attitude start/stop

(11) Monitor, control and analysis of derived data elements

(a) relative range rate

(b) LOS rates

(c) ΔV required

(d) ΔV to go

6.3.1.2.3.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.2.4 Station-Keeping Phase

6.3.1.2.4.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LOS)

(6) Monitor and control acceleration

(7) Monitor and control thrust level (RCS)

(8) Monitor autopilot modes

(a) attitude hold

(9) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control of attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.2.4.2 <u>Navigation and Guidance Functions</u>

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command of IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevation and declination)

(6) Management, monitor and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of composite data and prediction element

(a) target relative

(8) Management, monitor, command and analysis of time-to-go element

(a) RCS translation start/stop

(b) attitude start/stop

(9) Monitor, control and analysis of derived data elements

(a) relative range rate

(b) relative attitude

6.3.1.2.4.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.3 Mission Sequence: On Orbit

6.3.1.3.1 Hohmann Transfer Phase

6.3.1.3.1.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LV)

(6) Monitor and control acceleration

(7) Monitor and control thrust level (RCS)

(8) Monitor and control autopilot modes

(a) attitude hold

(9) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control of attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.3.1.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, and command IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevation and declination)

(6) Management, monitor and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of targeting elements

(a) velocity magnitude

(b) radial velocity

(c) position coordinates

(8) Management, monitor, command and analysis of time-to-go elements

(a) RMS engines start/stop

(b) attitude start/stop

(9) Monitor, control and analysis of derived data elements

(a) ΔV required

(b) ΔV to go

6.3.1.3.1.3 <u>Systems Monitoring Functions</u>

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.3.2 Out-of-Plane Phase

6.3.1.3.2.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LV)

(6) Monitor and control acceleration

(7) Monitor and control thrust level (RCS)

(8) Monitor autopilot modes

(a) attitude hold

(9) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control of attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.3.2.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command of IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevations and declination)

(6) Management, monitor and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of targeting elements

(a) velocity magnitude

(b) out-of-plane velocity

(c) position coordinates

(8) Management, monitor, command and analysis of time-to-go elements

(a) RCS engines start/stop

(b) attitude start/stop

(9) Monitor, control and analysis of derived data elements

(a) ΔV required

(b) ΔV to go

6.3.1.3.2.3 <u>Systems Monitoring Functions</u>

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.3.3 <u>Corrective Combination Phase</u>

6.3.1.3.3.1 <u>Control Functions</u>

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LV)

(6) Monitor and control acceleration

(7) Monitor and control thrust level (RCS)

(8) Monitor autopilot modes

(a) attitude hold

(9) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control of attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.3.3.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevation and declination)

(6) Management, monitor, and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of targeting elements

(a) velocity magnitude

(b) radial velocity

(c) out-of-plane velocity

(d) position coordinates

(8) Management, monitor, command and analysis of time-to-go elements

(a) RCS engines start/stop

(b) attitude start/stop

(9) Monitor, control and analysis of derived data elements

(a) ΔV required

(b) ΔV to go

6.3.1.3.3.3 Systems Monitoring and Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.4 Mission Sequence: Payload Handling

6.3.1.4.1 Docking Phase

6.3.1.4.1.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LOS)

(6) Monitor and control acceleration

(7) Monitor autopilot modes

(a) attitude hold

(8) Management, monitor and control attitude rates

(a) high-low

(9) Management, monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.4.1.2 <u>Navigation & Guidance Functions</u>

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and analysis of horizontal sensor (instrument local vertical)

(4) Management, monitor and analysis of trajectory element

(a) orbital parameters

(5) Management, monitor, control and analysis of targeting element

(a) target ephemeris

(6) Management, monitor, control and analysis of composite data and prediction element

(a) target relative

(7) Management, monitor, command and analysis of time-to-go element

(a) RCS translation start/stop

(8) Monitor, control and analysis of derived data element

(a) relative attitude

6.3.1.4.1.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.4.2 Undocking Phase

6.3.1.4.2.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LOS)

(6) Monitor and control acceleration

(7) Monitor autopilot modes

(a) attitude hold

(8) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(9) Management, monitor and control attitude rates

(a) high-low

(10) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.4.2.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, command and control of IMU alignment

(a) prelaunch

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Management, monitor and analysis of trajectory element

(a) orbital parameters

(6) Management, monitor, control and analysis of targeting element

(a) target ephemeris

(7) Management, monitor, control and analysis of composite data and prediction element

(a) target relative

(8) Mangement, monitor, command and analysis of time-to-go element

(a) RCS translation start/stop

(9) Monitor, control and analysis of derived data element

(a) relative attitude

6.3.1.4.2.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.4.3 Station-Keeping Phase

6.3.1.4.3.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LOS)

(6) Monitor and control acceleration

(7) Monitor and control autopilot modes

(a) attitude hold

(8) Monitor and control attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(9) Management, monitor and control attitude rates

(a) high-low

(10) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.4.3.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevation and declination)

(6) Management, monitor and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of targeting element

(a) target ephemeris

(8) Management, monitor, control and analysis of composite data and prediction element

(a) target relative

(9) Management, monitor, command and analysis of time-to-go elements

(a) RCS translation start/stop

(b) attitude start/stop

6.3.1.4.3.3 <u>Systems Monitoring Functions</u>

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.4.4 Payload Deploy/Retrieve Phase

6.3.1.4.4.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LOS)

(6) Monitor autopilot modes

(a) attitude hold

(7) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(8) Management, monitor and control attitude rates

(a) high-low

(9) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.4.4.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and analysis of horizontal sensor (indicator local vertical)

(4) Management, monitor and analysis of trajectory element

(a) orbital parameters

(5) Management, monitor, control and analysis of composite data and prediction element

(a) landing site relative

(6) Management, monitor, command and analysis of time-to-go element

(a) RCS translation start/stop

(7) Monitor, control and analysis of derived data elements

(a) relative range rate

(b) relative altitude

6.3.1.4.4.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.4.4.4 Payload Handling Functions

6.3.1.4.4.4.1 System Check-Out

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(1) Monitor and control slave arm hold downs

(2) Monitor and control cargo doors

(3) Monitor, activate and control support subsystems

(a) lighting

(b) TV cameras

(c) communications

(4) Monitor, activate and analyze electrical power to manipulator joints

(5) Deploy slave shoulders to operational location

(6) Deploy cargo bay TV cameras

(7) Monitor and activate TV controls

(8) Monitor and control master arm hold downs

(9) Activate power to No.1 master and slave

(10) Select and activate No.1 manipulator arm ratio

(11) Monitor and control No. 1 master and slave through operational range

(12) Deactivate No. 1 master and slave

(13) Activate power to No. 2 master and slave

(14) Select and activate No. 2 manipulator arm ratio

(15) Monitor and control No. 2 master and slave through operational range

(16) Conduct operational task using desired master/slave

6.3.1.4.4.4.2 Shuttle-to-Space Docking and Module Transfer

(1) System check-out completed

(2) Monitor and command position of manipulator arm

(3) Select and activate manipulator arm ratio

(4) Monitor and control final closure to slave reach envelope

(5) Monitor and control manipulator arms to grasp space station receptical

(6) Monitor, engage and lock terminal device

(7) Monitor and command computer control ΔV

(8) Monitor translation and docking

(9) Disengage terminal device

(10) Monitor and control slave to cargo bay

(11) Monitor and control manipulator arm to grasp and release module hold down

(12) Monitor and control TV camera alignment

(13) Monitor and control manipulator arm to move module from hold down fixture and clear of cargo bay

(14) Monitor and command computer to position module

(15) Monitor and control module insertion into docking port

(16) Disengage and control position of terminal device

(17) Monitor and control slave to stowed position

(18) Deactivate system

46 p 31-32 6.3.1.5 Mission Sequence: Return to Earth

6.3.1.5.1 Deorbit Phase

6.3.1.5.1.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control ΔV (LV)

(6) Monitor and control acceleration

(7) Monitor and control thrust level (OMS)

(8) Monitor autopilot modes

(a) attitude hold

(9) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) translation hand controller

(e) rotation hand controller select

(f) translation hand controller select

(g) rotation controller system

(h) translation controller system

(i) FDI reference

(j) FDI select

6.3.1.5.1.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevation and declination)

(6) Management, monitor and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of targeting elements

(a) time of landing

(b) landing site location

(8) Management, monitor, control and analysis of composite data and prediction elements

(a) ground tracks

(b) landing footprint

(9) Management, monitor, command and analysis of time-to-go elements

(a) OMS engines start/stop

(b) attitude start/stop

(c) touch down

(10) Monitor, control and analysis of derived data elements

(a) ΔV required

(b) ΔV to go

(c) down range to go

(d) cross range to go

6.3.1.5.1.3 <u>Systems Monitoring Functions</u>

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.5.2 <u>Pre-Entry Phase</u>

6.3.1.5.2.1 <u>Control Functions</u>

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control angular displacement elements

(a) angle of attack

(b) bank angle

(7) Monitor and control angular rates

(a) attack rate

(8) Monitor autopilot modes

(a) attitude hold

(9) Management and control of attitude manual mode elements

(a) rate condition attitude hold

(b) acceleration

(c) pulse

(10) Management, monitor and control attitude rates

(a) high-low

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) translation hand controller

(e) rotation hand controller select

(f) translation hand controller select

(g) rotation controller system

(h) translation controller system

(i) FDI reference

(j) FDI select

6.3.1.5.2.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor and command of IMU alignment

(a) course alignment

(4) Monitor and analysis of horizontal sensor (instrument local vertical)

(5) Monitor, command and analysis of star tracker (star elevation and declination)

(6) Management, monitor and analysis of trajectory element

(a) orbital parameters

(7) Management, monitor, control and analysis of composite data and prediction element

(a) landing footprint

(8) Management, monitor, command and analysis of time-to-go elements

(a) attitude start/stop

(b) touch down

(9) Monitor, control and analysis of derived data elements

(a) down range to go

(b) cross range to go

6.3.1.5.2.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.5.3 Entry Phase

6.3.1.5.3.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control angular deplacement

(a) angle of attack

(b) bank angle

(7) Management, monitor and control angular rates

(a) attack rate

(8) Monitor autopilot modes

(a) bank control

(b) attack control

(9) Management and control of attitude manual mode element

(a) rate condition attitude hold

(10) Monitor and control of control enable elements

(a) rotation hand controller

(b) translation hand controller

(c) rotation hand controller select

(d) translation hand controller select

(e) rotation controller system

(f) translation controller system

(g) FDI reference

(h) FDI select

6.3.1.5.3.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of temperature sensors

(a) body temperature

(4) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(e) flight path angle

(5) Management, monitor, control and analysis of targeting elements

(a) target ephemeris

(b) high key location

(6) Management, monitor, control and analysis of composite data and prediction elements

(a) altitude-velocity

(b) landing footprint

(7) Management, monitor, command and control of time-to-go elements

(a) touchdown

(8) Monitor, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) angle of attack rate

(d) angle of bank

(e) total heating

(f) down range to go

(g) cross range to go

(h) dynamic pressure

6.3.1.5.3.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.5.4 Energy Control Phase

6.3.1.5.4.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control angular displacement

(a) angle of attack

(b) bank angle

(7) Management, monitor and control angular rates

(a) attack rate

(8) Monitor autopilot modes

(a) bank control

(b) attack control

(9) Monitor and control aero surface position (indicator)

(10) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) FDI reference

(e) FDI select

6.3.1.5.4.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of DME (distance to station)

(4) Monitor, control and analysis of VOR (bearing to station)

(5) Monitor, control and analysis of baro. altimeter (altitude)

(6) Monitor, control and analysis of speed and vertical speed

(a) IAS and mach no.

(b) rate of descent

(7) Monitor, control and analysis of temperature sensors

(a) total temperature

(8) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(e) flight path angle

(9) Management, monitor, control and analysis of targeting elements

(a) target ephemeris

(b) low key location

(10) Management, monitor, control, and analysis of composite data and prediction elements

(a) landing site relative

(b) energy range

(11) Management, monitor, command and analysis of time-to-go element

(a) touchdown

(12) Management, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) angle of attack rate

(d) angle of bank

(e) down range to go

(f) cross range to go

(g) percent L/D

(h) total energy

(i) true airspeed

(j) ground speed

(k) dynamic pressure

6.3.1.5.4.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.5.5 Final Approach Phase

6.3.1.5.5.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control angular displacement

(a) angle of attack

(b) bank angle

(7) Monitor and control angular rates

(a) attack rate

(8) Monitor autopilot modes

(a) bank control

(b) attack control

(c) attitude hold

(d) VOR, GS, LOC hold

(e) heading hold

(f) auto land

(9) Management and control of attitude manual mode elements

(a) bank condition

(b) flight path angle condition

(c) rate condition

(10) Monitor and control of aero surface position (indicator)

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) ABES throttles

(e) FDI reference

(f) FDI select

6.3.1.5.5.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of DME (distance to station)

(4) Monitor, control and analysis of speed and vertical speed

(a) IAS and mach no.

(b) rate of descent

(6) Monitor, control and analysis of temperature sensors

(a) total temperature

(7) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(e) flight path angle

(8) Management, monitor, control and analysis of targeting elements

(a) target ephemeris

(b) low key location

(9) Management, monitor, control and analysis of composite data and prediction elements

(a) landing site relative

(b) energy range

(c) altitude range

(d) azimuth range

(10) Management, monitor, command and analysis of time-to-go element

(a) touchdown

(11) Monitor, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) angle of attack rate

(d) angle of bank

(e) percent L/D

(f) total energy

(g) true airspeed

(h) ground speed

(i) dynamic pressure

6.3.1.5.5.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion systems

(g) payload

6.3.1.5.6 Roll-Out Phase

6.3.1.5.6.1 Control Functions

(1) Control of attitude manual mode element

(a) nose wheel steering

(2) Monitor and control of aero surface position (indicator)

(3) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) ABES throttles

(4) Monitor and control chute deployment

6.3.1.5.6.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU attitude

(2) Monitor, control and analysis of precision DME (distance to touchdown)

(3) Monitor, control and analysis of baro. altimeter (altitude)

(4) Monitor, control and analysis of temperature sensors

(a) total temperature

(5) Monitor, control and analysis of radar altimeter (precision altitude)

(6) Management, monitor and analysis of trajectory elements

(a) velocity

(b) heading

6.3.1.5.6.3 System Monitoring Functions

Monitor and control system status

(a) caution and warning

(b) communications

(c) electrical power

(d) mechanical power

(e) propulsion system

(f) payload

6.3.1.6 Mission Sequence: Ferry

6.3.1.6.1 Preflight Phase

6.3.1.6.1.1 Control Functions

(1) Monitor and control attitude

(2) Monitor autopilot modes

(a) bank control

(b) attack control

(c) attitude hold

(d) VOR, GS, LOC hold

(e) heading hold

(f) area navigation

(g) auto land

(3) Management and control of attitude manual mode elements

(a) bank condition

(b) flight path angle condition

(c) nose wheel steering

(d) rate condition

(4) Monitor and control gyro aero surface position (indicator)

(5) Control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) ABES throttles

(e) FDI reference

(f) FDI select

6.3.1.6.1.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU attitude

(2) Monitor, command and control of IMU alignment

(a) prelaunch

(3) Monitor, command and control of baro. altimeter

(4) Management, monitor, control and analysis of targeting elements

(a) position coordinates

(b) time of landing

(c) landing site location

6.3.1.6.1.3 System Monitoring Functions

Monitor and control system status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion system

6.3.1.6.2 Take-Off Phase

6.3.1.6.2.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control thrust level

(7) Monitor and control angular displacement

(a) angle of attack

(8) Monitor and control angular rates

(a) attack rate

(9) Management and control of attitude manual mode elements

(a) bank condition

(b) flight path angle condition

(c) nose wheel steering

(d) rate condition

(10) Monitor and control aero surface position (indicator)

(11) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) ABES throttles

(e) FDI reference

(f) FDI select

6.3.1.6.2.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of baro. altimeter

(4) Monitor, control and analysis of temperature sensors

(a) total temperature

(5) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) flight path angle

(6) Management, monitor, control and analysis of targeting element

(a) position coordinates

(7) Management, monitor, command and analysis of time-to-go element

(a) touchdown

(8) Monitor, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) angle of bank

(d) percent L/D

(e) true airspeed

(f) dynamic pressure

6.3.1.6.2.3 <u>System Monitoring Functions</u>

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion system

6.3.1.6.3 Cruise Phase

6.3.1.6.3.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control thrust level

(7) Monitor and control angular displacement

(a) angle of attack

(8) Monitor and control angular rates

(9) Management and monitor autopilot modes

(a) attitude hold

(b) VOR, GS, LOC hold

(c) heading hold

(d) area navigation

(10) Management and control of attitude manual mode elements

(a) bank condition

(b) flight path angle condition

(c) rate condition

(11) Monitor and control aero surface position (indicator)

(12) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) ABES throttles

(e) FDI reference

(f) FDI select

6.3.1.6.3.2 Navigation and Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of DME (distance to station)

(4) Monitor, control and analysis of VOR (bearing to station)

(5) Monitor, control and analysis of baro. altimeter

(6) Monitor, control and analysis of temperature sensor element

(a) total temperature

(7) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(e) flight path angle

(8) Management, monitor, control and analysis of targeting elements

(a) position coordinates

(b) time of landing

(c) landing site location

(9) Management, monitor, command and analysis of composite data and prediction element

(a) ground tracks

(10) Monitor, control and analysis of time-to-go element

(a) touchdown

(11) Monitor, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) angle of attack rate

(d) angle of bank

(e) percent L/D

(f) true airspeed

(g) ground speed

(h) dynamic pressure

6.3.1.6.3.3 System Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion system

6.3.1.6.4 Inflight Refueling Phase

6.3.1.6.4.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rates

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control thrust level

(7) Monitor and control angular displacement

(a) angle of attack

(8) Monitor and control angular rates

(9) Management and monitor autopilot modes

(a) attitude hold

(b) VOR, GS, LOC hold

(c) heading hold

(d) area navigation

(10) Management and control attitude manual mode elements

(a) bank condition

(b) flight path angle condition

(c) rate condition

(11) Monitor and control aero surface position (indicator)

(12) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) ABES throttles

(e) FDI reference

(f) FDI select

6.3.1.6.4.2 Navigation and Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of DME (distance to tanker)

(4) Monitor, control and analysis of VOR (bearing to tanker)

(5) Monitor, control and analysis of baro. altimeter

(6) Monitor, control and analysis of temperature sensor element

(a) total temperature

(7) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(d) latitude and longitude

(e) flight path angle

(8) Management, monitor, control and analysis of targeting elements

(a) position coordinates

(b) time of rendezvous

(c) rendezvous location

(9) Management, monitor, control and analysis of composite data and prediction elements

(a) ground track

(10) Monitor, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) angle of attack rate

(d) angle of bank

(e) percent L/D

(f) true airspeed

(g) ground speed

(h) dynamic pressure

6.3.1.6.4.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion system

6.3.1.6.5 Descent and Landing Phase

6.3.1.6.5.1 Control Functions

(1) Monitor and control attitude

(2) Monitor and control attitude rate

(3) Monitor and control attitude command

(4) Monitor and control attitude errors

(5) Monitor and control acceleration

(6) Monitor and control thrust level

(7) Monitor and control angular displacement

(a) angle of attack

(8) Management, monitor and control angular rates

(a) attack rate

(9) Management and monitor autopilot modes

(a) bank control

(b) attack control

(c) attitude hold

(d) VOR, GS, LOC hold

(e) heading hold

(f) auto land

(10) Management, monitor and control attitude manual mode

(a) bank condition

(b) flight path angle control

(c) nose wheel steering

(d) rate condition

(11) Management, monitor and control aero surface position (indicator)

(12) Monitor and control of control enable elements

(a) rotation hand controller

(b) rudder pedals

(c) speed brake

(d) ABES throttles

(e) FDI reference

(f) FDI select

(13) Monitor and control chute deployment

6.3.1.6.5.2 Navigation & Guidance Functions

(1) Monitor, control and analysis of IMU acceleration

(2) Monitor, control and analysis of IMU attitude

(3) Monitor, control and analysis of DME (distance to station)

(4) Monitor, control and analysis of precision DME (distance to touchdown)

(5) Monitor, control and analysis of baro. altimeter

(6) Monitor, control and analysis of temperature sensor element

(a) total temperature

(7) Monitor, control and analysis of radar altimeter (precision altitude)

(8) Management, monitor and analysis of trajectory elements

(a) altitude

(b) velocity

(c) heading

(9) Management, monitor, control and analysis of targeting elements

(a) position coordinates

(b) low key location

(10) Management, monitor, control and analysis of composite data and prediction elements

(a) energy range

(b) altitude range

(c) azimuth range

(11) Management, monitor, command and analysis of time-to-go element

(a) touchdown

(12) Monitor, control and analysis of derived data elements

(a) altitude rate

(b) angle of attack

(c) angle of attack rate

(d) angle of bank

(e) percent L/D

(f) total energy

(g) true airspeed

(h) ground speed

(i) dynamic pressure

6.3.1.6.5.3 Systems Monitoring Functions

Monitor and control systems status

(a) caution and warning

(b) communications

(c) electrical power

(d) environmental control and life support

(e) mechanical power

(f) propulsion system

6.3.2 Mission Specialist

Limited reference data were available which would define the task responsibilities of the Mission Specialist as a member of the Shuttle crew. Determination of the tasks performed by the Mission Specialist are based on data contained in a concise job description (Reference 181) and a telephone interview (Reference No. 255).

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p 3-159 The Mission Specialist Station is located in the aft section of the upper crew deck. He is provided with a panel which will permit the necessary interfacing between the payload and the orbiter on-board systems. The panel also contains the necessary controls for providing payload data to ground control. A computer monitor is provided at the station for determining the status of the payload. Depending upon the payload being carried, provisions are made on the mission specialist panel for installation of payload unique panels.

255 p. 3 The following is a list of responsibilities assigned to the Mission Specialist:

(1) Provide the necessary interface between the payload and orbiter operations.

(2) Provide the necessary communications configuration to transmit data from the Payload/Payload Specialist to ground control

(3) Perform EVA and IVA

(4) Provide back-up to the Commander/Pilot for operation of the RMS

(5) Perform experimental operations

(6) Perform malfunction correction

6.3.2.1 Payload Interface

The tasks associated with payload interface will require the Mission Specialist to monitor and control the output of the various orbiter systems to provide the environment required of the payload during the various phases of the mission. Based on the payload, the Mission Specialist will be allocated a given amount of consumables (e.g., power). He will be required to manage the use of the consumables to ensure that the status of the payload conforms to mission objectives. The Mission Specialist would be required to perform the duties associated with payload interface during the following phases of the mission:

(1) Ascent

(2) Rendezvous

(3) Orbit

(4) Payload Operations

(5) Return

(6) Abort

6.3.2.2 Payload Communications

The Mission Specialist will be required to perform tasks which will permit the transfer of payload data from the orbiter to ground control. In performing these tasks, the Mission Specialist will be required to select, control and monitor the appropriate communication configuration which will permit the transmission of data elements from the payload or Payload Specialist to the ground for monitoring, or to receive instructions concerning payload status. These duties would be performed during the following mission phases:

(1) Ascent

(2) Rendezvous

(3) Orbit

(4) Payload operations

(5) Return

6.3.2.3 EVA/IVA

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Primary responsibility for all EVA and IVA are vested in the Mission Specialist. Several Space Station

subsystems have unscheduled maintenance requirements that will require EVA operational support for their accomplishment. The subsystems requiring EVA support for unscheduled maintenance are as follows:

ISS	Replace parabolic antenna drive assembly
	Replace antenna power amplifier
RCS	Replace cyro tanks
Structure	Repair or replace meteoroid shielding
ECLSS	Replace radiator section

Items requiring IVA support are as follows:

Fire	Post-fire repair
Explosion	Post-explosion maintenance
Depressurization	Structural repair

The Mission Specialist would be required to perform duties pertaining to EVA and IVA during the orbit and payload operation phases of the mission.

6.3.2.4 RMS Operation

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The Mission Specialist is designated as back-up to the Commander/Pilot for operation of the RMS. In order to accomplish these tasks, he must be proficient in the operation of the RMS. The tasks associated with RMS operation are outlined under Commander/Pilot Task Requirements (Reference

para. 6.3.1.4.4.4). The Mission Specialist would be performing these tasks during the payload operation phase of the mission.

6.3.2.5 Experiment Operations

On some missions, the Mission Specialist will be required to perform experiment operations. It is anticipated that the Mission Specialist will be assigned these tasks on those missions where a Payload Specialist is not a member of the crew, or to assist the Payload Specialist in performing an experiment. The tasks required of the Mission Specialist when performing this role would be dependent upon the type of equipment being carried in the cargo bay and the associated mission objectives. Duties associated with experiment operations would be performed during the orbit and payload operation phases of the mission.

6.3.2.6 Malfunction Correction

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Systems management provisions include on-board functions required to determine vehicle status, configuration, performance and operational readiness. These provisions include caution and warning, performance monitoring and inflight data recording for ground analysis. Although some systems contain provisions for automatic switching of redundant elements or for automatically safing failed elements, most redundancy management is accomplished manually based on data made available to the crew through the performance monitoring

system and dedicated cockpit displays. While the caution and warning system annunciates conditions requiring immediate attention (gross failures), the performance and monitoring system detects less urgent off-nominal conditions. The performance monitoring system also monitors lower criticality data, particularly in nonavionic subsystems where an out-of-tolerance condition does not necessarily indicate a failure, only a need for adjustment. The Mission Specialist, at the direction of the Commander, is required to perform the necessary fault correction. He may be directed to perform these duties during all phases of the mission.

6.3.3 Payload Specialist

181 p.1 The Payload Specialist is required to have a detailed knowledge of the equipment being carried in the cargo bay. This includes:

(1) Payload instruments

(2) Operation of the equipment

(3) Requirements and objectives to be accomplished

(4) Operation of on-board support equipment associated with the cargo

The background and experience of the Payload Specialist, in turn, must be specific in nature, e.g., Astronomer, Chemist, Electrical Engineer, and is oriented toward the nature of the payload being carried on a specific mission.

While the Payload Specialist can be considered a crew position title, the associated duties encompasses a multitude of disciplines. As a result, one mission may require a Payload Specialist who is a Geologist; another, a Payload Specialist who is an expert in meteorology. The tasks required of this crew position would be dependent upon the type of equipment being carried in the cargo bay on a given mission. Similarly, the number of Payload Specialists assigned to a mission could vary from none to more than one again depending upon the cargo.

Because of the diversity of skills required of the Payload Specialist, the crew position is unique since it would require a crew member who is trained for a specific type mission. In addition, the specialty would include members from all disciplines required to accomplish the objectives of the Space Shuttle Program. Payload Specialist training would tend to be by discipline. Only general training- e.g., space shuttle overview, shuttle habitability, environmental acclimation - could be taught collectively. Specific tasks requirements for this crew position cannot be determined until more detailed data are available on the types of missions which will be flown in the Space Shuttle Program.

6.4 Work Station Intra-Relationship

181 p 1 Coordination of actions within a crew is of prime importance to ensure the optimum degree of mission success and

safety during all phases of operation. This coordination is not necessarily limited to actions alone. Complete familiarity with one's crew position, the responsibilities thereof, and a working knowledge of the other crew members' duties contributes immeasurably toward crew coordination. Each crew member must be constantly on the alert for any deviation or discrepancy which may affect the successful accomplishment of the mission, and notify the responsible crew member. Liaison between individuals concerned must be established prior to initiating any action or procedure which will alter the vehicle configuration or require correlation of activities between crew members.

Since the shuttle vehicle design is based upon a two-pilot flight crew, operating procedures are to be shared by the Commander and Pilot similar to conventional two-pilot aircraft. Sharing of these tasks would require a high degree of coordination between these two crew members. Unlike conventional aircraft, where the proficiency level of the second Pilot is usually not as high as the Commander, in shuttle vehicle operation both Pilots would be equally proficient.

In addition to those tasks required for vehicle operation, the Commander/Pilot operates the RMS during payload handling operations. In this phase of the mission, coordination is required among the Pilot, RMS Operator, and Mission Specialist.

The Pilot would be responsible for keeping the vehicle within a station-keeping envelope so that the RMS Operator could perform the required task. In order to keep the vehicle within the station-keeping envelope, the Pilot would require information on the relative position of the target and manipulator arm(s). The Mission Specialist would be required to prepare the payload for independent functioning prior to deployment or to place the payload into an appropriate environment on retrieval.

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The Mission Specialist is responsible for the interface between the payload and orbiter operations. Payload caution and warning data are the only information provided at the Commander/Pilot Station. As a result, the Mission Specialist would be required to keep the Commander appraised of the payload status. Where orbiter systems are required to support the payload, the Mission Specialist would coordinate the required action with the Commander. Based upon the assumption that the Mission Specialist would also perform duties comparable to a flight engineer on conventional-type aircraft, the Mission Specialist would coordinate systems operations with the Commander. In the event of a system malfunction, he, together with the Commander, would analyze the problems and take the required action.

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The Payload Specialist is required to have a detailed knowledge of the equipment being carried in the cargo bay. To assist in the evaluation of the payload equipment status, payload unique panels are installed at this station. These panels present the only source of intelligence on the status of the payload. The Payload Specialist would provide inputs to the Commander on equipment status and advise him of required action. Since the Mission Specialist is responsible for the interface between the payload and orbiter subsystems, close coordination would be required between the Payload and Mission Specialists. These two, in turn, would coordinate their actions with the Commander.

7.0 Crew Station

7.1 Physical Environment

The physical environment of the Simulator Crew Station must faithfully simulate that of the actual vehicle in all respects perceptible to the crew members during the performance of their duties. This includes, among other things, size, lighting, color, texture, controls, placards, temperature and mobility provisions.

Ideally, utilization of actual vehicle equipment would satisfy this requirement completely but this would be prohibitive for several reasons:

a) Availability and cost

b) Structurally not necessarily adaptable to simulator requirements, i.e,

1) Attachment to motion base

2) No provision for support of Visual System

3) Actual structure not able to be sectionalized for Part Task Training Modules.

c) Exterior not compatible with exterior requirements for simulator (i.e., exceeds dimensions necessary for simulation)

d) Airborne equipment not necessarily compatible with synthetically activated equipment.

e) Some airborne equipment not adequate for repetitive failures

Thus a study is necessary to evaluate and identify those actual components which could economically be utilized, and define those

which must be completely simulated and those which could be simulated in appearance only.

No crew functions are performed on the lower deck other than those associated with life support and as such simulation of it will not be required except for a separate part task mock-up. Motion considerations also preclude incorporation of the lower deck into the active SMS crew station configuration.

The Shuttle Crew Station on the upper deck at the time of this report is in a state of flux. The best concept available is documented by reference 135. A horizontal and vertical cross-section of the cabin is shown in Figures 7-1 and 7-2 respectively.

7.1.1 Work Station Consoles

7.1.1.1 Requirements

The configuration of all Work Station Consoles must duplicate the actual equipment as perceptible to the crew. Actual construction techniques and portions not visible to the crew may depart from actual Vehicle construction.

The Orbiter is currently configured to have five Work Stations namely,

1. Commanders Flight Station
2. Pilot's Flight Station
3. Orbit Station (formerly the Payload Handling Station)
4. Mission Monitoring Station
5. Payload Monitoring Station

The shape and location of these stations are denoted in Figure 7-1. A sixth station for photographic purposes may exist but sufficient data is not available presently to define whether this exists or not.

7.1.1.2 Rationale

The synthesized equipment may require more space or different access than actual equipment. The actual Vehicle consoles may be an integral part of the Vehicle structure whereas ease of fabrication, maintenance and assembly may justify an alternate approach for the simulator components.

7.1.1.3 Assumptions

Not applicable.

7.1.1.4 Data Reference

135 - Preliminary Control and Display Panel Sketch

7.1.2 Controls and Displays

7.1.2.1 Requirements

All controls must reflect the physical appearance and dynamic characteristics of the actual Vehicle controls, including travel, force, hysterisis, damping and response for normal and failed modes of operation. Similarly, the Displays must reflect the same detail, brightness and scope of that in the actual vehicle.

The current configuration of panels for each work station is shown in Table 7-1. Reproducible drawings of these panels are not currently available but they are contained in reference 135.

7.1.2.2 Rationale

All features must individually and collectively reproduce the real-world environment of the actual Vehicle to produce the psychological effect of realism during the training program and develop proficiency in the actuation of controls.

7.1.2.3 Assumptions

None.

7.1.2.4 Data Reference

Document #135

Table 7.1

Item No.	Item Name	Station: Flight	Station: Mission Monitor	Station: Orbit
L1	Left Console-AFT Panel	X		
L2	Left Console-FWD Panel	X		
L3	Main Instrum. Panel	X		
L4	Glare Shield Panel	X		
L5	Ctr Pedestal-FWD Panel	X		
L6	CTR Pedestal-AFT Panel	X		
L7	Right Console-FWD Panel	X		
L8	Right Console-AFT Panel	X		
L9	Hand Controller-Rot.(2)	X		
L10	Hand Controller-Transl.(2)	X		
L11	Parking Brake Control	X		
L12	O'HD Panel-FWD	X		
L13	O'HD Panel-AFT-L.H.	X		
L14	O'HD Panel-AFT-CTR	X		
L15	O'HD Panel-AFT-R.H.	X		
L16	O'HD Panel-Wing-L.H.	X		
L17	O'HD Panel-Wing-R.H.	X		
L18	Circ.Brkr Panel-L.H.Upper	X		
L19	Cir Panel-L.H.Lower	X		
L20	Communications Panel	X		
L21	Performance Monitor, Panel	X		
L22	Circ.Brkr Panel-R.H.Upper	X		
L23	Temp.Ctl Panel	X		
L24	Fire Detector Panel	X		
L25	Circ.Brkr Panel-R.H.Lower	X		
L26	Payload Environ.Ctl Panel		X	
L27	Recorder Panel		X	
L28	Payload Circ.Brkr Panel		X	
L29	CRT Panel		X	
L30	Tape Control Panel		X	
L31	Orbit Sta.-Upper L.H.Panel			X
L32	Orbit Sta.-Upper R.H.Panel			X
L33	Orbit Sta.-Lower L.H. Panel			X
L34	Orbit Sta.-Lower R.H. Panel			X

7.1.3 Interior Equipment

7.1.3.1 Requirements

All interior equipment including hand holds, lighting fixtures, stowage compartments, linings, decals, etc., shall duplicate that of the Vehicle in all respects perceptible to the crew. No data is currently available on the Orbiter's interior equipment

7.1.3.2 Rationale

To stimulate the sensation of realism of a mission and to acquaint the crewmen with equipment location.

7.1.3.3 Assumptions

None.

7.1.3.4 Data Reference

None.

7.1.4 Lighting

7.1.4.1 Requirements

All lighting fixtures and controls shall duplicate the actual Vehicle in detail, location and intensity. Likely these will be actual Vehicle components.

In addition it shall be possible to adjust the light intensity to optimize the Visual Display. Also, emergency lights will be required for safety in the event of Simulator Power failure. No data is currently available on the Orbiter's interior lighting.

7.1.4.2 Rationale

To promote familiarization of various lighting combinations and controls, also to reduce to ambient below real-world intensity to enhance the realism of the visual display scene and eliminate unwanted reflections and glare.

7.1.4.3 Assumptions

None.

7.1.4.4 Reference

None.

7.1.5 Heating/Air Conditioning

7.1.5.1 Requirements

The heating/air conditioning capability of the SMS should be capable of producing an ambient environment similar to that prevailing in the actual Vehicle insofar as it provides a cue of malfunction or reflects mode of flight of the crewman. Rate of change of environment shall not duplicate spacecraft conditions. The Heating/Air Conditioning systems shall be capable of producing an ambient of 65°F to 85°F in response to control settings by the crew member or Instructor override Vehicle Controls.

No data is currently available to define the detailed Orbiter's requirements.

The possibility of suit system simulation may exist, however, due to the vehicle requirements for shirt sleeve environment this is a remote possibility.

7.1.5.2 Rationale

The spacecraft is designed for shirt sleeve environment but in space the Vehicle has the capability of infinitely rapid, and hazardous, change. Thus the cost of simulation would be prohibitive and the training value of such simulation negligible. A commercially available air conditioner sized to offset the heat generated by instruments, lights, crew load and visual load shall be deemed adequate with switching logic to permit simulation of cues which could be encountered under various Mission Modes.

7.1.5.3 Assumptions

No extremes of ambient are necessary.

7.1.5.4 Reference

None.

7.1.6 Ingress/Egress

7.1.6.1 Requirements

Ingress/Egress conditions in the simulator shall be representative of those encountered in the Vehicle for both Normal and Emergency Conditions except for those hatches, employed under zero-g conditions, between the upper and lower deck. All hand-holds, steps and latching devices shall be simulated.

Entry for Part Task training may be excluded from this requirement and tailored to adapt to the individual modules.

No data is curently available in sufficient detail to define the Orbiter's Ingress/Egress detailed requirements.

7.1.6.2 Rationale

Ingress/Egress of normal Launch, Emergency Escape and Post Landing are sufficiently time-related to training to impart realism and require preficiency in execution.

Ingress/Egress and mobility during part-task training under "zero-g" conditions cannot be remotely simulated and thus serve no, or perhaps even negative, training value.

Ingress with the Vehicle x-axis vertical will require sufficient dexterity, strength and impact on realism to warrant inclusion as the count-down, readiness check and preflight preparation are performed with the crew seated on wall-mounted seats, facing the ceiling.

7.1.6.3 Assumptions

None.

7.1.6.4 Data Reference

#164 - N.A.R. Version #13 Layouts

#135 - C&D Layout

8.0 Visual Cues

8.1 The Human Visual System - Some Observations

8.1.1 Introduction

The purpose of the visual portion of the overall study is to define the requirements for a visual system which will be utilized in a full mission simulator for effective crew training in the various Shuttle Missions. Initially, the Shuttle Vehicle and Mission Report defines the potential visual scenes based on the Shuttle's cockpit configuration and performance capabilities during the various missions. Hence, the response characteristics of the human visual system are relevant.

The human visual system is sensitive to radiant energy from about 380 to 740 nanometers in wavelength. Light is defined (1)"as radiant energy evaluated according to its capacity to produce visual sensation." To see an object, light of suitable quality and intensity from the object must form an image of adequate size, contrast, and duration on the retina for the retina to transform the light energy into nerve energy, and the nerve impulses must be conducted to the brain and integrated into consciousness.(1).

Light enters the eye through the cornea and is imaged on a layer called the retina in the back of the eye, so that different parts of the retina receive light from different parts of the visual field outside. The retina is not absolutely uniform: there is a place, a spot, in the center of our field of view which we use when we are trying to see things very carefully, and at which we have the greatest acuity of vision; it is called the fovea or macula. The off-axis viewing, as we can

immediately appreciate from our experience in looking at things, are not as effective for seeing detail as is the foveal vision. There is also a spot in the retina where the nerves carrying all the information run-out; that is, a blind spot. There is no sensitive part of the retina here (2).

Seeing is a perceptual process that is affected by and incorporates other sensations, emotions, association mechanisms simultaneously active with vision, education and past experience. It varies with the condition of the individual and the entities must be statistical probabilities of seeing rather than absolute values (1). During the tests to determine the statistical responses of subjects in the presence of visual objects the following definitions are used:

1) detection implies a positive response ("yes") on the part of the subject to a stimulus presentation the name of which has been given in the instructions (as in the case "Tell me if you see light"). A variation of this procedure may require that the subject name the stimulus (e.g., "I see a light"). In such a case the instructions (e.g., "Tell me what you see") do not involve the name of the object (3).

2) recognition (and identification) involve naming responses for different objects. The objects are identified by name, and the names are tabulated as either "correct" or "incorrect" (3).

3) judgements also involve naming, for example, in the verbalizing of appropriate color terms (3).

8.1.2 Visual System Simulation Parameters

Performance parameters as they relate to the human visual system functioning are discussed in the following paragraphs. These parameters represent those areas to which specification and numerical values can be assigned in order to provide a basis for an objective evaluation of a device whose acceptability is predominantly subjective.

8.1.2.1 Field of View

The field of view of a visual system refers to the horizontal (azimuth) and vertical (elevation) angles over which the visual scene is displayed. Normally, it is measured from a nominal position and direction and should encompass the total space within which pertinent visual cues may be contained (4).

The average monocular visual field (Figure 8.1-1) for the right eye is:

a.

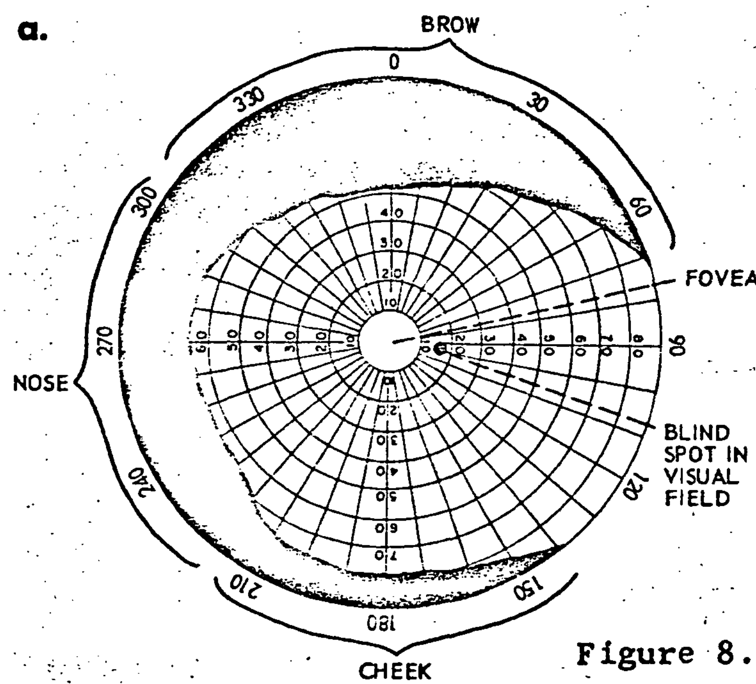

Figure 8.1-1

At the center of the chart is the fovea. The head and eyes are motionless. The nasal field is to the left, and the temporal field to the right of the chart. Visual fields are mapped with a two-degree achromatic circular Target with a luminance of about mililamberts (5).

The binocular visual field of view (Fig. 8.1-2) with head and eyes fixed is:

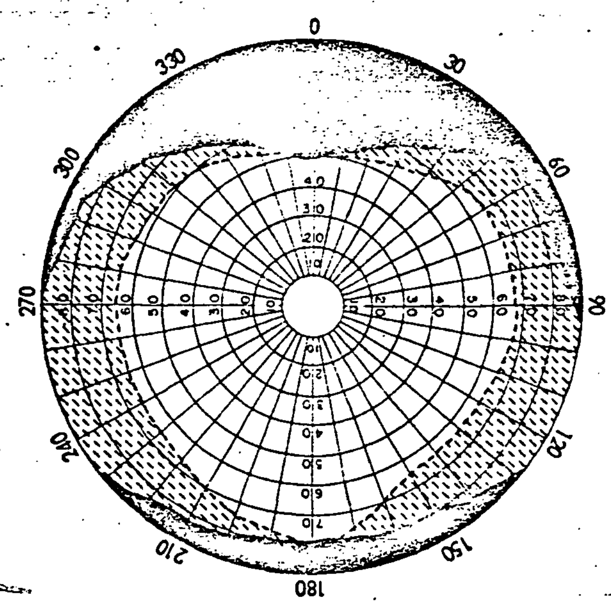

Figure 8.1-2

The central white portion represents the region seen by both eyes. The gray portions, right and left, represent the regions seen by the right and left eyes, respectively. The cut-off by the brows, cheeks, and nose

is shown by the black area (5).

Primarily, the lack of the binocular cue, i.e., stereoscopic vision, was a significant factor in contributing to probe contact failure during Martin-Marietta's simulation of the remote manipulator system of the Shuttle. In particular, the use of mono-TV viewing and the resultant lack of depth perception resulted in a persistent problem in the operator's ability to judge probe - target distance. The general opinion of operators was that the mono-TV was "adequate" and could be successfully used for the simulated task, but that TV with depth perception would be a definite improvement (Shuttle Reference #22, pg.VI-43). However, this statement has not been supported by performance data. Stereoscopic vision occurs, when a subject regards an object in space, the retinal image in the right eye is different from the retina image in the left eye. The difference in retinal images serves as the basis for many spatial discrimentations. Another binocular cue, i.e., convergence is not of concern since convergence cues cannot be differentially effective for objects at distances greater than several yards and the length of the remote manipulator system is fifty (50) feet (3). In summary, the monocular cues for depth perception (3) were not sufficient in reducing the number of probe contact failures in Martin-Marietta simulation tests.

8.1.2.2 Brightness

Luminous flux is the time rate of the flow of light and indicates the intensity of a source. The unit of flux is the lumen.

Illuminance can be defined as the luminous flux incident (falling) upon a surface. A typical unit is the footcandle. The equation for illuminance is:

$$E = \frac{F}{A}$$ where E = illuminance in footcandles

F = incident flux in lumens

A = area of the illuminated surface in square feet

Luminance is the brightness of an illuminated surface. If all of the illuminance falling on a perfectly diffusing surface were reradiated by the surface, then the luminance would numerically equal the illuminance. But, since this doesn't happen, we must take into account the reflection factor of the surface which is the ratio:

$$\frac{\text{reflected light}}{\text{incident light}}$$

Thus, we can staee that luminance = illuminance x reflection factor. A typical unit of luminance is footlambert when the unit for illuminance is footcandle. (Note: one lambert is equal to one Lumen/square centimeter or one lambert = 929 footlamberts)(6).

Table 8.1-1 illustrates the enormous range of luminances encountered by man on earth and in space. The values given are approximate and generally represent limits as indicated by the notes. The units are millilamberts (5).

Luminance in mL		Object	Notes
1×10^{9}	7×10^{8}	Sun	Viewed from outside earth's atmosphere
	4.4×10^{8}	Sun	Viewed from the earth
1×10^{8}	8×10^{7}	A-Bomb	Fireball 4 miles from point of detonation of an 800 KT weapon.
1×10^{7}			
1×10^{6}			
1×10^{5}			
	1.58×10^{4}	Venus	Assume albedo (r) of 0.59 viewed from outside atmosphere
	9.4×10^{3}	Earth	Viewed from space with cloud cover (r=0.8)
1×10^{4}	6.4×10^{3}	Mercury	Viewed from outside atmosphere (r=0.069)
	4.3×10^{3}	Earth	Viewed in January from outside atmosphere, no clouds (r = 0.39)
	2.9×10^{3}	*Jupiter*	*Viewed from outside atmosphere (r=0.56)*
	2×10^{3}	Sky	Average sky on clear day
	1.2×10^{3}	Moon	Full moon viewed from outside of atmosphere (r = 0.073)
1×10^{3}	9.6×10^{2}	Saturn	Viewed from outside atmosphere (r=0.63)
	9×10^{2}	Mars	Viewed from outside atmosphere (r=0.15)
	8×10^{2}	Moon	Full moon viewed from earth
	5×10^{2}	Sky	Average sky on cloudy day
	2.4×10^{2}	Uranus	Viewed from outside the earth (r = 0.63)
1×10^{2}	1.1×10^{2}	Neptune	Viewed from outside atmosphere (r=0.73)
	2×10^{1}	White paper in good reading light	
	1.6×10^{1}	Movie screen (indoors)	
1×10	1×10^{1}	TV screen	
	7×10^{0}	Pluto	Viewed from outside the atmosphere
1×10^{0}	8×10^{-1}	Snow in light of full moon	
1×10^{-1}			
	2×10^{-2}	Lower limit for useful color vision	
1×10^{-2}	7.5×10^{-3}	Earth	Viewed from outside atmosphere with full moon
	1×10^{-3}	Upper limit for night vision	
1×10^{-3}			
1×10^{-4}			
	3×10^{-5}	Earth	Viewed from outside atmosphere at night with airglow, starlight, and zodiacal light providing illumination
	1×10^{5}	Absolute threshold for dark adapted human eye, lower limit for night vision	
1×10^{-5}	1×10^{-5}	Sky	Moonless night sky viewed from earth
5×10^{-6}			
4×10^{-6}			
3×10^{-6}			
2×10^{-6}			
1×10^{-6}	1×10^{-6}	Space background	Background luminance formed by starlight, zodiacal and galactic light.

Table 8.1-1

However, the human visual system is very poor at making absolute judgements of brightness; for example, the illusion of looking

directly at the sun can be achieved with 15 or 20 foot-lamberts after suitable dark adaptation (4), and changes of luminance in a ratio of 10 to 1 or even 100 to 1 are scarcely noticed if the change is not sudden (7).

8.1.2.3 Contrast

Contrast is defined (4) as the difference in luminance between an object and its surround divided by the luminance of the surround, i.e.;

$$C = \frac{I_o - I_s}{I_s}$$

Modulation is defined as (8):

$$M = \frac{I_o - I_s}{I_o + I_s}$$

Figures 8.1-3 and 8.1-4 shows the sighting range (distance in feet) of circular targets viewed against the sky with background luminance 1000 millilamberts (full daylight) and 0.0001 millilamberts (starlight) respectively at probability of detection of 95%. These figures were selected because they are typical of the Shuttle crew environment. Meteoroligical range is the distance at which apparent contrast is reduced by atmospheric scatter to 2% of inherent contrast between the object and sky. The following is an example of the use of the nomogram. Find the range that an object 100 sq. ft. in area could be seen in starlight when the meteoroligical range is 150,000 ft. and the contrast of the object and sky is 0.8. A straight line across meets

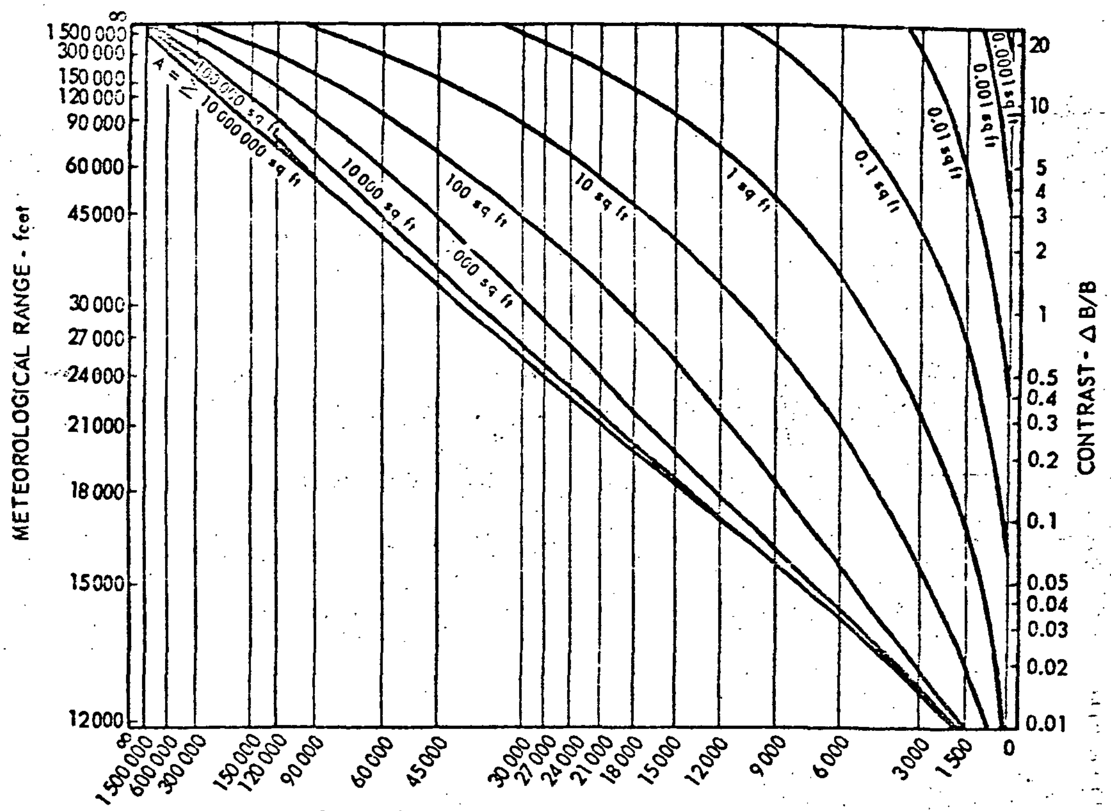

Figure 8.1-3 SIGHTING RANGE - feet

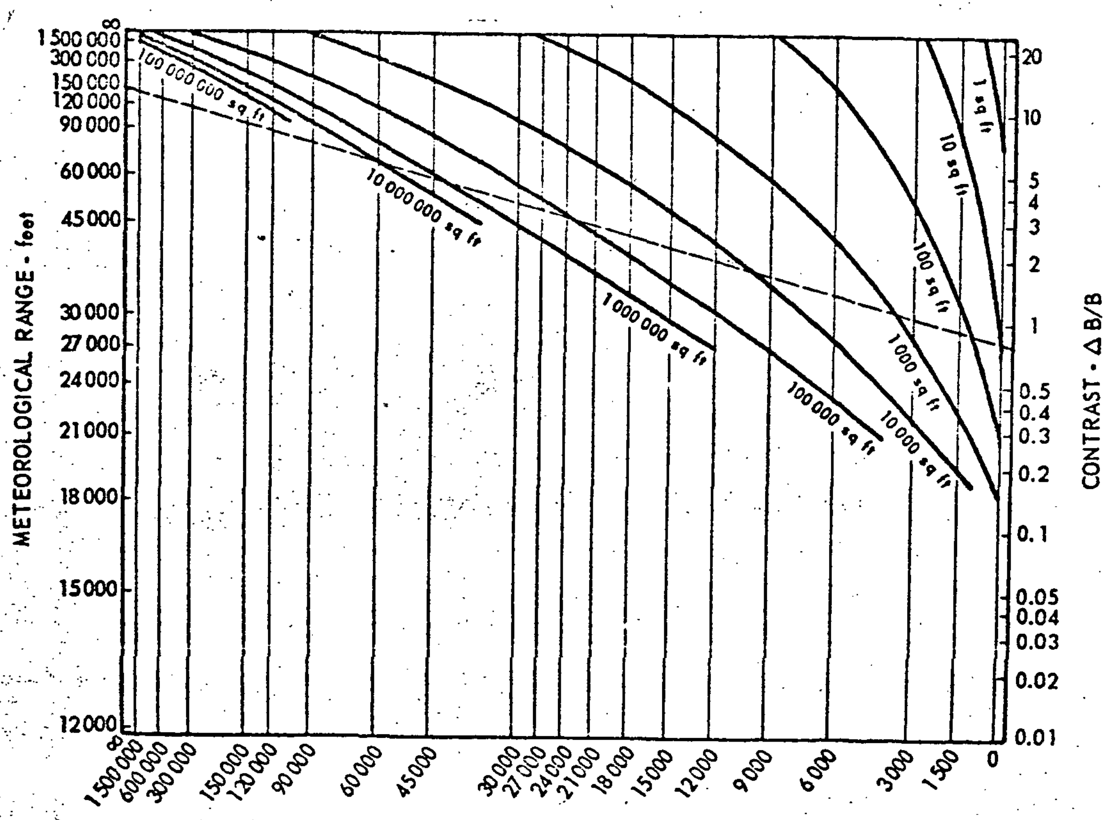

Figure 8.1-4

the given range and contrast. The range is read off where the line intersects the 100 sq. ft. curve. Under these conditions a 100 sq. ft. target will be sighted with a probability of detection of 95% at 1200 ft. (5).

8.1.2.4 Resolution

One of the reasons for discussing brightness and contrast is that the discussion of resolution would be in a coherent manner. Resolution of the human visual system means the smallest space it can detect between the parts of a target consisting of alternate black and white equally spaced bars. The resolving power of the human visual system is the function of many variables such as illumination, contrast, shape and duration of a stimili (see Figure 8.1-5). For this test, the target used was a bright bar in a Landolt-ring placed in an array of complete circles. The actual target was, therefore, a single narrow bright line (8).

8.1.2.5 Color

A general definition of color is the pigmentation of substances in the environment. This includes both the selective pigments that yield hues and the unselective pigments that yield black, gray, and white. In this sense of the term, the color of a thing helps to specify the material substance of it - that is, what the object is composed of. Hence the ability to discriminate colors is part of the more general ability to discriminate substances as discussed previously.

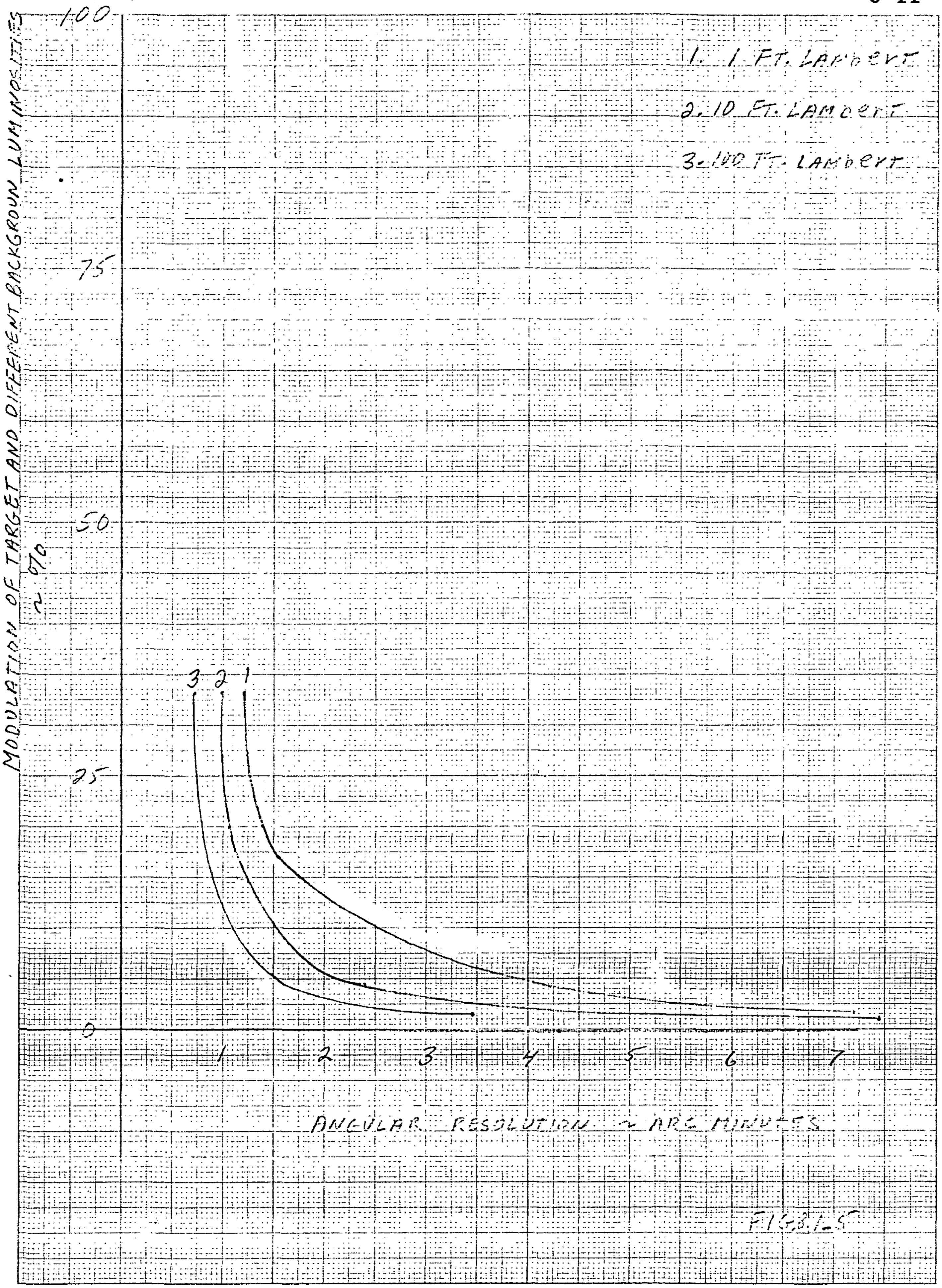
1. 1 FT. LAMBERT
2. 10 FT. LAMBERT
3. 100 FT. LAMBERT
MODULATION OF TARGET AND DIFFERENT BACKGROUN LUMINOSITIES ~ %
100
75
50
25
0
3 2 1
1
2
3
4
5
6
7
ANGULAR RESOLUTION ~ ARC MINUTES

FIG 8.1-5

A color discussion could include monocular field of view for chromatic targets (5) and the spectral sensitivity of the eye in the dark and in light (2), however, these discussions are not relevant in their application to the Shuttle program. Rather the color transition of the sky during launch and entry, the color content of the earth surface observed in orbit, horizon detail, and the various lights (for example runway, payload and other aircraft).

The color transition initiation from blue to black is estimated to occur at 100,000 ft. and terminate at 200,000 ft. The color content of the earth varies since for such observations the atmosphere presents itself as a formidable source of masking and interference (10). However, pictures taken in orbit, for example NASA Advanced Technology Satellite III, should be made available and reviewed. With respect to horizon detail, Simons reported three horizons at 102,000 ft.:...."a true horizon where the sky meets the rim of the earth...the horizon formed by the interface between the tops of cloud layers and the sky... and the dusty haziness in the white layer right above the horizon...." (11). He also observed at 102,000 ft. the lack of readily noticeable sky above, the complexity of the sky at different times of the day, the auroral display, the nontwinkling stars and the "halo zone" a few degrees immediately below the horizon - additional faint dim bands of blue, sharply but faintly edged against the sky, well above the haze layer of the earth's atmosphere (11). The color of the various lights encountered by the crew during the Shuttle missions are discussed in

the subsequent sections by phase.

8.1.2.6 References

1) Military Standardization Handbook Optical Design - Department of Defense - MIL-HDBK-141

2) Lectures On Physics - Richard P. Feynman, Robert B. Leighton, and Matthew Sands - Addison Wesley Publishing Company, Inc. 1964

3) Vision and Visual Perception - Clarence H. Graham editor- John Wiley and Sons, Inc. 1965

4) Study to Determine Requirements For Undergraduate Pilot Training Research Simulation System - Technical Report AFHRL-TR-68-11 July 1969

5) Biostronautics Data Book - Paul Webb M.D. editor - NASA SP-3006 1964

6) How to Understand and Use Photometric Quantities - Kodak Tech Bits - Eastman Kodak Company 1965

7) Spectral Response of The Eye - George A. Leavitt - Optical Spectra-September 1971

8) Matching An Image Display to a Human Observer - Donald C. Winter - Electro Optical Design August 1971

9) The Senses Considered As Perceptual Systems - James J. Gibson - Houghton Mifflin Company 1966

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11) Physiology of Man In Space - J. H. U. Brown - Academic Press 1963

REF. KEY

8.2 Windows

8.2.1 Description

The primary flight (forward) station and the payload handling station (orbit station) contain windows providing an external view. (164)

The primary flight (forward) station is organized in a typical pilot/copilot relationship with sufficient duplication of displays and controls to permit the vehicle to be piloted from either seat and permit one-man emergency return. (166 pg.3-115) This arrangement results in a cockpit fairly similar to that of a standard transport aircraft. (36 pg.4-194) There exists six windows in the pilot/copilot station. (166 pg.3-148) Each window contains a three-pane redundant system where the middle crew cabin pane (fused silica for thermal protection) is also sealed to contain cabin pressure. (166 pg.3-37) Rain, fog, and frost removal is required for these windows. The liquid spray, rain-removal system, as implemented on the B-1, as well as the alcohol spray are candidates for rain and frost removal. (166 pg.3-20) The prelaunch GN_2 (i.e., gaseous nitrogen) purge of the inner cavities prevents fogging during boost, and entry-induced temperatures similarly preclude fogging. A GN_2 purge will prevent the interpane fogging during horizontal flight tests and ferry operations. Also shades are provided for light and radiant heat control in boost, entry and orbital flight. (166 pg.3-147)

164 and 36 pg.4-378 The payload handling specialist occupies the payload handling station (aft-facing station) in a semi-standing position; it has a one piece upward facing and rear-facing window to permit a wide range of vision aft, downward into the cargo bay and upward ($-Z_B$ direction), including some forward vision.

166 pg.3-147 Each crew station external window may serve as a photographic station to assure coverage of various orbital operational tasks. Mounts and alignment aids maybe required to assure camera support and optical alignment dictate.

8.2.2. Field of View

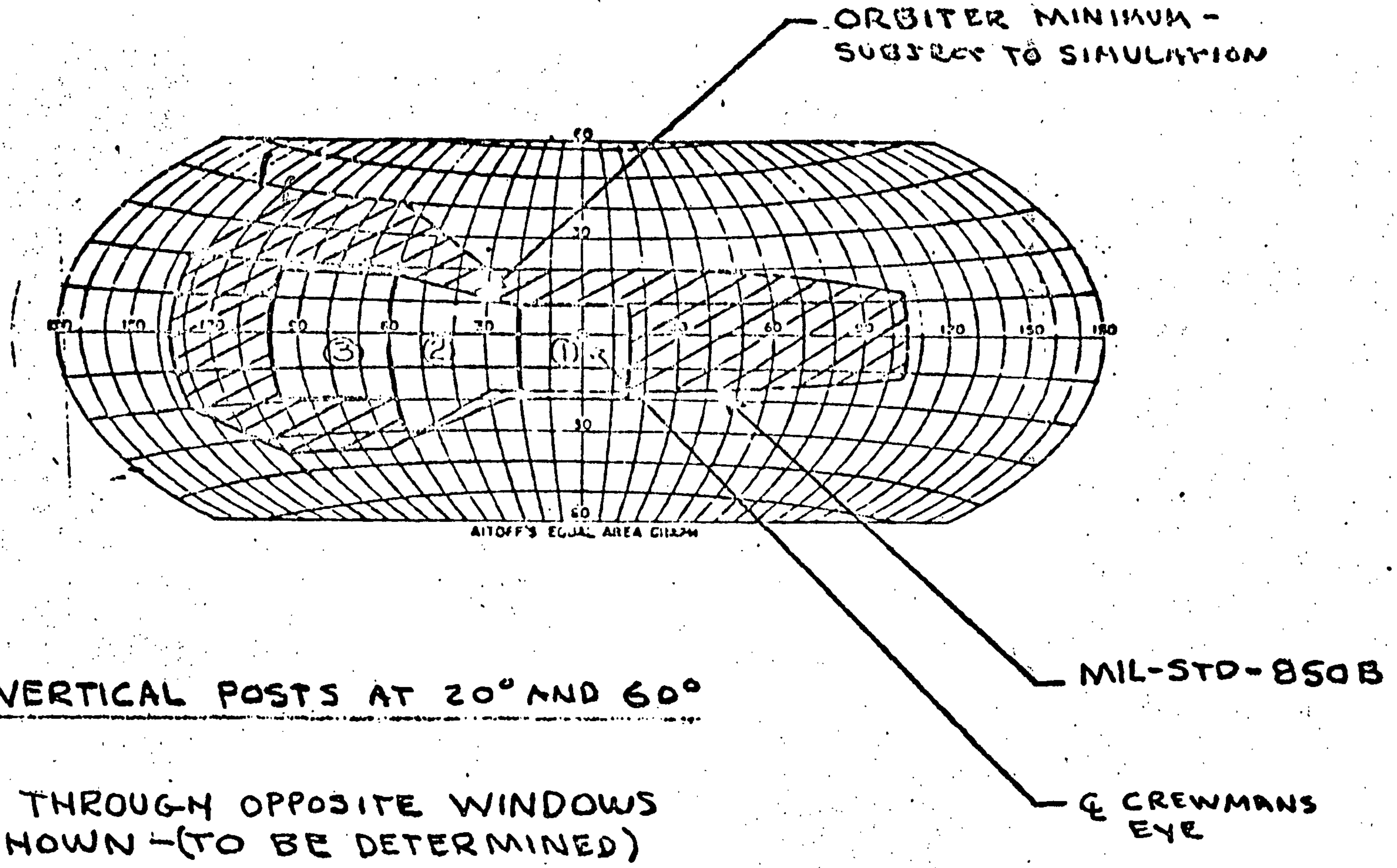
8.2.2.1 Forward Windows

180 pg.2 Figure 8.2-1 illustrates the pilot visibility through the three windows left of the centerline. The copilot visibility through the three windows right of the centerline is the mirror image of Figure 8.2-1. The field of view from either of the two viewing positions through all six windows has not been determined. The total horizontal field of view is esti-
166 pg.3-31 mated to be approximately 200°. When the vehicle is at rest on the runway the x_B axis is 3° 15' below the horizontal.

166 pg.3-147 Crew seats and restraints accommodate a combination of spacecraft and aircraft functions with provisions for adjustment and positioning to satisfy launch through landing conditions. Also the flight crew seats have additional

FIGURE I A

ORBITER APPROACH AND LANDING MINIMUM VISION REQUIREMENT



- NOTE VERTICAL POSTS AT 20° AND 60°

- VISION THROUGH OPPOSITE WINDOWS NOT SHOWN -(TO BE DETERMINED)

LEFT SIDE SHOWN
RIGHT SIDE OPPOSITE

Figure 8.2-1

adjustments to provide the required visibility, reach, and mobility necessary to pilot the vehicle. The excursions of these seat movements have not been determined, therefore, a viewing point envelope for the pilot and copilot cannot be defined.

164 The coordinates of the nominal viewing position has been specified for the average man to be: station line = 460 inches, water line = 469 inches and buttock line = 22 inches. The vertical field of view straight ahead with respect to this nominal viewing position is 10° up and 20° down. The water line of the nominal viewing position will vary from 406 inches (fifth percentile man) to 410 inches (ninety-five percentile man).* The vertical field of view for non-average size stationary crewmen because of the ± 2 inch water line change cannot be defined since the window geometry and forward panel locations have not been determined.

180 pg.1 The 10° vertical field of view above the horizontal is sufficient for the pilot to see the entire length of a 10,000 ft. runway at preflare altitude (1050 ft.) with worst case pitch-down transients in orbiter pitch attitude. Sufficient

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Human Engineering Guide to Equipment Design - Sponsored by Joint Army-Navy-Air Force Sterring Committee - McGraw - Hill Book Company pg. 518

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180 pg.6 down vision to see 2^{o} below the horizon at main gear touchdown, at worse case nose up attitude (tail scrape angle of 18^{o}) dictated a minimum of 20^{o} down vision on the pilot's centerline.

8.2.2.2 Payload Handling Station

The nominal viewing point, the division of the total vertical field of view into above and below the horizontal, the horizontal field of view, the viewing point envelope and the window geometry have not been identified. This area is exceptionally weak because of this lack of information.

8.2.3 Assumptions

The payload handling station windows are glass panels that are covered by the cargo doors during launch and entry.

REF. KEY

8.3 Ascent Phase (Vertical Launch to Orbit Insertion

The primary objective of the ascent phase is insertion of the orbiter into a 50 x 100 nautical mile orbit. The ascent phase sequence includes: (1) mated flight, i.e., booster assists orbiter to the desired separation conditions, (2) separation, i.e., separate booster from orbiter, and (3) orbiter insertion, i.s., orbiter continues its flight and inserts into orbit. [166 pg.iii]

The nominal ascent trajectory profile includes a five second vertical boost phase, followed by a pitchover and flight at the desired attitude angle. Roll to the flight azimuth is accomplished during the pitchover. The orbiter is oriented in an inverted position during ascent to maximize performance and abort capability. The abort SRM's are jettisoned unused when the critical abort period ends 30 seconds after lift-off. At approximately 109 seconds after ignition SRMs staging occurs. Insertion occurs for a polar mission 561 seconds after ignition and for an easterly mission 547 seconds. [166 pg.2-34] [166 pg.2-15] [166 pg.2-10 & pg.2-17] [166 pg.2-17 & 2-10]

8.3.1 Scene Content

8.3.1.1 Horizon. This refers to the boundary between the earth and skyfield. It is usually rough at low altitudes, due to the presence of terrain features. As altitude increases, it becomes smoother since the terrain features defining the

horizon are at a greater distance. At orbital altitudes, the curvature of the earth may be perceptible.

8.3.1.2 Terrain. This includes all the visible features of the earth's surface, both natural and artificial. The launch area with gantry is prominent in the visual scene during vertical launch. Also, the terrain scene depends upon launch site, (i.e,, KSC or WTR).

8.3.1.3 Celestial Bodies. These include sun, moon, planets, stars, comets, and meteors; the last four are more visible during the hours of darkness. The sun also casts shadows.

8.3.1.4 Own Vehicle. Included here are those portions of the
166 pg.2-17 vehicle external to the windows that can be seen through the
& 164 windows. The external hydrogen-oxygen tank is visible in the
164 & 167 mated configuration with respect to an approximate eye position
pg.2-5 1500 inches from the external hydrogen-oxygen tank tip and 360 inches above the external hydrogen-oxygen tank centerline, and within a vertical field of view that extends to 20° down. The abort SRM's are not visible in the mated configuration and after separation. Also, the 156 inch SRM's are not visible in the mated configuration and after separation since the initial
166 pg.2-47 trajectory of the solid rocket motors have a $+Z_B$ component as illustrated in Fig. 8.3-1.

F-398-8-A

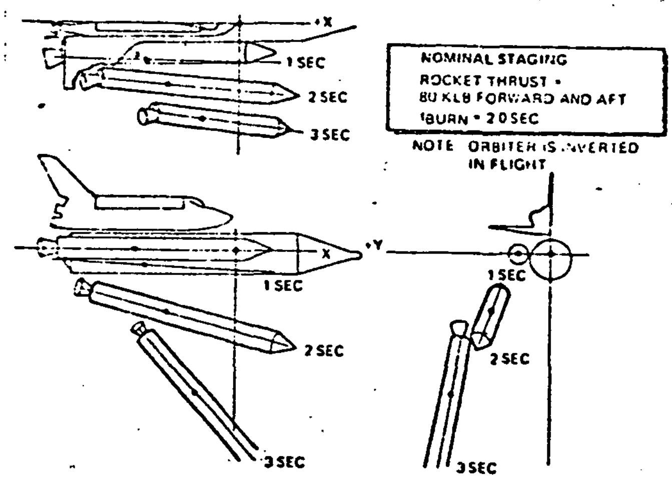

Figure 8.3-1 *Successful SRM Separation Under Nominal Conditions*

8.3.1.5 Atmospheric Effects. These include clouds, contrails, smoke, fog banks, and the like, located in the atmospheric belt. Objects of the class cannot only be seen, but can occult the scene behind them partially or completely.

8.3.2 Color

Colors that may be present during this phase include the color transition of the sky from a blue to black, the blue-green of the ocean, various shades of green and brown from the natural landscape, and the colors of cultural objects, such
166 pg.2-47, 2-47, 2-48 as red roofs. White clouds may also be present. The color content of the scene will change during separation due to the ignition of the forward SRM separation rockets.

8.3.3 Illuminators/Non-Illuminators

Definition:

(1) Illuminators: Those light sources that illuminate reflective objects to a significant extent.

(2) Non-Illuminators: Those that can be seen because of their own luminescence, but which do not illuminate anything.

Examples of illuminators during the ascent phase are: sun, moon, SRM separation rockets' plume and ground lighting such as streetlights. Examples of non-illuminators are stars and ground light sources such as lighted windows. The Ascent Phase could occur during daylight or darkness.

8.3.4 Displacements

8.3.4.1 Translation

From KSC

166
pg.2-25,
46
167
pg.2-5

$$0 \le |x_E| \le 4.0 \times 10^6 \text{ ft.}$$

$$0 \le |y_E| \le 5.2 \times 10^6 \text{ ft.}$$

$$-80 \ge z_E \ge -350{,}000 \text{ ft.}$$

From WTR

$$0 \le |x_E| \le 5.2 \times 10^6 \text{ ft.}$$

$$0 \le |y_E| \le 1.0 \times 10^6 \text{ ft.}$$

$$-80 \ge z_E \ge -350{,}000 \text{ ft.}$$

8.3.4.2 Rotation (B-Frame with respect to B-Frame at launch)

From KSC

166
pg.2-25

$$-90^\circ \le \phi \le 90^\circ$$

$$-10^\circ \le \theta \le 110^\circ$$

$$-45^\circ \le \psi \le 25^\circ$$

From WTR

$$-90^\circ \le \phi \le 90^\circ$$

$$-10^\circ \le \theta \le 110^\circ$$

$$-10^\circ \le \psi \le 10^\circ$$

8.3.5 Velocity

8.3.5.1 Translation

From KSC

170
pg.6

$$0 \le |\dot{x}_E| \le 20{,}000 \text{ fps}$$

$$0 \le |\dot{y}_E| \le 26{,}000 \text{ fps}$$

$$0 \le |\dot{z}_E| \le 3{,}000 \text{ fps}$$

From WTR

170
pg.6

$0 \le |\dot{x}_E| \le 26{,}000$ fps

$0 \le |\dot{y}_E| \le 7{,}500$ fps

$0 \le |\dot{z}_E| \le 3{,}000$ fps

8.3.5.2 Rotation

$0 \le |p_B| \le 20^\circ/\text{sec}$

$0 \le |q_B| \le 5^\circ/\text{sec}$

$0 \le |r_B| \le 5^\circ/\text{sec}$

8.3.6 Acceleration

8.3.6.1 Translation

From KSC

170
pg.6
166
pg.2-91

$0 \le |\ddot{x}_E| \le 80$ ft./sec^2

$0 \le |\ddot{y}_E| \le 100$ ft./sec^2

$0 \le |\ddot{z}_E| \le 60$ ft./sec^2

From WTR

$0 \le |\ddot{x}_E| \le 100$ ft./sec^2

$0 \le |\ddot{y}_E| \le 20$ ft./sec^2

$0 \le |\ddot{z}_E| \le 60$ ft./sec^2

8.3.6.2 Rotation

$0 \le |\dot{p}_B| \le 1.5$ rad/sec^2

$0 \le |\dot{q}_B| \le 0.5$ rad/sec^2

$0 \le |\dot{r}_B| \le 0.5$ rad/sec^2

8.3.7 Assumptions

1) Launch Earth Axes System - The origin of this system lies on the surface of the earth fixed at the launch site. The X_E axis is positive North, Y_E is positive East and the Z_E axis is positive toward the center of the earth.

2) The launch azimuth from KSC ranges from 44° to 110°.

3) The direction of the launches from WTR will be south in order to attain a polar orbit.

8.4 Abort (Vertical Launch)

The objective of the abort phase is to interrupt the normal launch sequence when the abort situation occurs and carry the abort operation to a point where a nominal sequence can be re-entered. There exists five abort modes:

166 pg. 2-48 2-50

(1) Abort SRM (launch commit to 30 seconds). The orbiter separates from the tank-SRM cluster assisted by the ASRM to facilitate safe separation and returns to launch site.

166 pg. 2-51

(2) Orbiter Glide (30 seconds to 86 seconds). Orbiter separation from the tank-SRM cluster can be accomplished aerodynamically, i.e., without thrust augmentation, in this flight regime and utilizes a glide return to the launch site.

(3) Orbiter Powered Return to Site (86 to 300 seconds). The orbiter returns to site by means of a powered maneuver with orbiter main engines. Variations depending on ascent conditions are: (a) abort before nominal staging, and (b) abort after nominal staging.

166 pg. 2-51 2-52

(4) Orbiter Once-Around Orbit (300 to 440 seconds) For loss of thrust from a single main engine during this time interval, the abort mode is once around to the launch site.

166 pg. 2-52

(5) Orbiter Abort to Orbit (440 to 551 seconds) After loss of thrust from a single engine after 440 seconds of flight, the orbiter continues to orbit.

166 pg.3-81 SRM thrust termination is provided for abort modes by means of two symmetrical blowout ports formed in each forward motor dome by the ignition of linear shaped charges. Exhaust stacks are provided to direct the gas discharge through the forward attach structure and away from the orbiter.

8.4.1 Scene Content

8.4.1.1 Horizon - Same as 8.3.1.1

8.4.1.2 Terrain - Similar to 8.3.1.2 but different areas of
166 pg.5-37 the earth are involved, depending upon the abort mode employed. Also the landing strip at KSC is a 10,000 ft. x 150 ft. runway with a 1500 ft. overrun, tower, operations building, utilities, runway lighting, ILS and navigation aids. This runway will be
166 pg.2-91 a new construction northwest of VAB. The pilot's perception of the horizon and runway in unpowered approach and landing is considered to be critical in order to safely accomplish the task. In addition, for modes 4 and 5, the day/night terminator is visible.

8.4.1.3 Celestial Bodies - Same as 8.3.1.3

8.4.1.4 Orbiting Vehicles - These include U.S. and Russian spacecraft and "space junk" from previous launches. They would be visible during abort modes 4 and 5 (i.e., orbiter once-around and orbiter abort to orbit), and not during other abort modes.

8.4.1.5 Own Vehicle - Similar to 8.3.1.4 for abort modes 5, 4 and part of 3 when the abort takes place after nominal staging. In addition, as in section 8.5.1.5, the tank is visible in order to verify a safe separation. For the remaining portion of mode 3 and the entire mode 2, the orbiter separates aerodynamically from the tank-SRM cluster. In mode 1 the ASRM assist in separation from the cluser. In either case the tank-SRM cluster is not visible (Figure 8.4-1).

166
pg.2-48

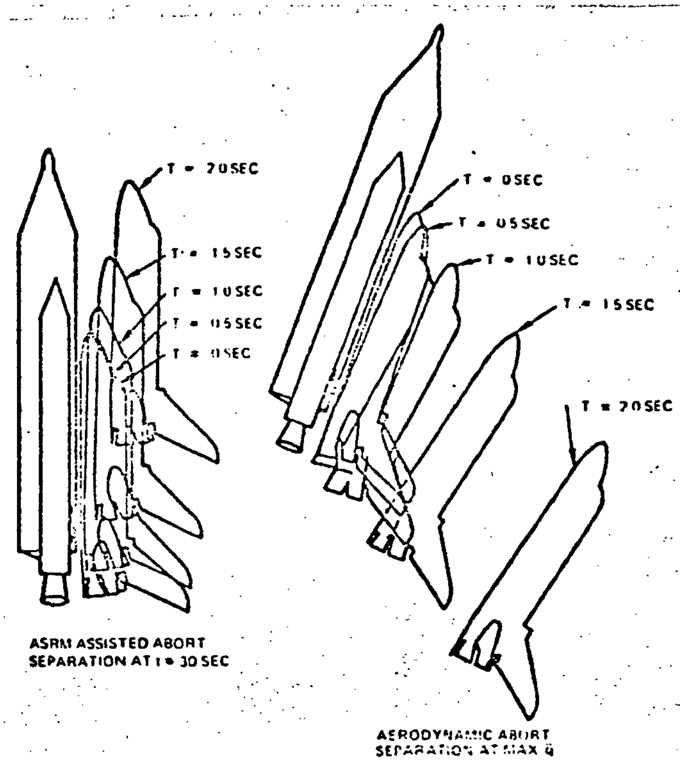

Figure 8.4-1 *Positive Separation of Orbiter From Tank and SRM's*

8.4.1.6 Atmospheric Effects - Same as 2.1.5.

8.4.1.7 Other Aircraft - Normal air traffic, which is kept from the vicinity of the launch site during launch, may be visible during abort.

8.4.2 Color

In addition to the objects whose colors were enumerated in 8.3.2, there is the possibility that orbiting bodies may be visible during abort modes 4 and 5 (i.e., orbiter once-around and orbiter abort to orbit). These bodies would probably be black and white, for the most part, for thermal control. Also, for aborts before nominal staging, the colors in the scene will change due to the plume from SRM thrust termination through the forward firing blowout ports. Category II approach runway lighting colors* include red (e.g., red barrettes on each side of the centerline), white (e.g., touchdown zone), green (e.g., runway threshold), yellow (e.g., runway remaining edge lights) and blue (e.g , taxiway edge at intersection).*

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* International Civil Aviation Organization Annex 14 with attachments. Fifth Edition, May 1969.

8.4.3 Illuminators/Non-Illuminators

Examples of illuminators during the abort phase are: sun, moon, the plume from SRM thrust termination through the forward firing blowout ports, SRM separation rockets' plume, general lighting such as streetlights and orbiter's landing lights. Examples of non-illuminators are: stars, ground light sources such as lighted windows, runway lighting, and runway light of other aircraft. The abort phase could occur in daylight or darkness.

166 pg.3-148

8.4.4 Displacements

8.4.4.1 Translation

166 pg.2-50 170 pg.73

Mode 1: From KSC and WTR

$$0 \leq |x_E| \leq 60{,}000 \text{ ft.}$$

$$0 \leq |y_E| \leq 60{,}000 \text{ ft.}$$

$$-80 \geq z_E \geq -20{,}000 \text{ ft.}$$

Mode 2: From KSC and WTR

166 pg.2-51

$$0 \leq |x_E| \leq 220 \times 10^3 \text{ ft.}$$

$$0 \leq |y_E| \leq 220 \times 10^3 \text{ ft.}$$

$$-80 \geq z_E \geq -100 \times 10^3 \text{ ft.}$$

Mode 3: From KSC

166 pg.2-51

$$0 \leq |x_E| \leq 1.8 \times 10^6 \text{ ft.}$$

$$0 \leq |y_E| \leq 2.5 \times 10^6 \text{ ft.}$$

$$-80 \geq z_E \geq -400 \times 10^3 \text{ ft.}$$

From WTR

166 pg.2-51

$$0 \leq |x_E| \leq 2.5 \times 10^6 \text{ ft.}$$

$$0 \leq |y_E| \leq 100 \times 10^3 \text{ ft.}$$

$$-80 \geq z_E \geq -400 \times 10^3 \text{ ft.}$$

Mode 4 and 5: From KSC and WTR

166 pg. 2-52

$$-80 \geq z_E \geq -800 \times 10^3 \text{ ft.}$$

8.4.4.2 Rotational (B-Frame with Respect to B-Frame at launch)

The rotational excursions for all three angles are continuous for all five abort modes.

8.4.5 Velocity

8.4.5.1 Translation

170 pg.73

Mode 1: From KSC and WTR

$$0 \leq |\dot{x}_E| \leq 1000 \text{ fps}$$

$$0 \leq |\dot{y}_E| \leq 1000 \text{ fps}$$

$$0 \leq |\dot{z}_E| \leq 1000 \text{ fps}$$

Mode 2: From KSC and WTR

166 pg.2-51

$$0 \leq |\dot{x}_E| \leq 3000 \text{ fps}$$

$$0 \leq |\dot{y}_E| \leq 3000 \text{ fps}$$

$$0 \leq |\dot{z}_E| \leq 3000 \text{ fps}$$

Mode 3: From KSC

166 pg.2-51

$$0 \leq |\dot{x}_E| \leq 6500 \text{ fps}$$

$$0 \leq |\dot{y}_E| \leq 9000 \text{ fps}$$

$$0 \leq |\dot{z}_E| \leq 3000 \text{ fps}$$

From WTR

$$0 \leq |\dot{x}_E| \leq 9000 \text{ fps}$$

$$0 \leq |\dot{y}_E| \leq 4000 \text{ fps}$$

$$0 \leq |\dot{z}_E| \leq 3000 \text{ fps}$$

Mode 4 and 5: From KSC and WTR

166
pg.2-52

$$0 \leq V \leq 27{,}000 \text{ fps}$$

8.4.5.2 Rotation

170
pg.73,
74&75

Mode 1:

$$0 \leq |p_B| \leq 40^\circ/\text{sec}$$

$$0 \leq |q_B| \leq 10^\circ/\text{sec}$$

$$0 \leq |r_B| \leq 10^\circ/\text{sec}$$

170
pg.89,
90

Mode 2:

$$0 \leq |p_B| \leq 40^\circ/\text{sec}$$

$$0 \leq |q_B| \leq 20^\circ/\text{sec}$$

$$0 \leq |r_B| \leq 15^\circ/\text{sec}$$

Mode 3:

$$0 \leq |p_B| \leq 40^\circ/\text{sec}$$

$$0 \leq |q_B| \leq 20^\circ/\text{sec}$$

$$0 \leq |r_B| \leq 15^\circ/\text{sec}$$

166
pg.2-69

Modes 4 and 5:

$$0 \leq |p_B| \leq 20^\circ/\text{sec}$$

$$0 \leq |q_B| \leq 5^\circ/\text{sec}$$

$$0 \leq |r_B| \leq 5^\circ/\text{sec}$$

8.4.6 Acceleration

8.4.6.1 Translation

166
pg.2-51

Mode 1: $0 \leq |\ddot{x}_E| \leq 100$ ft/sec^2

$0 \leq |\ddot{y}_E| \leq 100$ ft/sec^2

$0 \leq |\ddot{z}_E| \leq 100$ ft/sec^2

170
pg.6
&
166
pg.2-51

Modes 2 and 3: $0 \leq |\ddot{x}_E| \leq 130$ ft/sec^2

$0 \leq |\ddot{y}_E| \leq 130$ ft/sec^2

$0 \leq |\ddot{z}_E| \leq 100$ ft/sec^2

Modes 4 and 5: $0 \leq |\ddot{x}_E| \leq 100$ ft/sec

$0 \leq |\ddot{y}_E| \leq 100$ ft/sec

$0 \leq |\ddot{z}_E| \leq 60$ ft/sec

8.4.6.2 Rotation

170
pg. 74

Mode 1: $0 \leq |\dot{p}_B| \leq 1$ rad/sec^2

$0 \leq |\dot{q}_B| \leq 0.25$ rad/sec^2

$0 \leq |\dot{r}_B| \leq 0.25$ rad/sec^2

170
pg.89

Mode 2: $0 \leq |\dot{p}_B| \leq 1$ rad/sec^2

$0 \leq |\dot{q}_B| \leq 0.5$ rad/sec^2

$0 \leq |\dot{r}_B| \leq 0.5$ rad/sec^2

<u>Mode 3, 4 and 5</u>: $0 \leq |\dot{p}_B| \leq 1.5 \text{ rad/sec}^2$

$0 \leq |\dot{q}_B| \leq 0.5 \text{ rad/sec}^2$

$0 \leq |\dot{r}_B| \leq 0.5 \text{ rad/sec}^2$

8.4.7 <u>Assumptions</u>

1) Same as assumption (1) Section 8.3.7.

2) The landing strips at both KSC and WTR will meet FAA Category II requirements. Also, the basic weather minimums are the same as FAA Category II conditions.

The reason Category II, rather than I or III was selected relates to current air transport practices. Ground facilities (radio aids, runway lighting), aircraft equipment, pilot training, and procedures combine to make Category II landing by commercial aircraft routine. Category III landings are still somewhat experimental; few aircraft and only one commercial airport (Dulles) are presently certified for Category III. The landing strips at KSC and WTR, if used by support aircraft, would require Category II certification to be of maximum use. Hence the assumption of Category II capability at the two landing strips appears reasonable.

3) Normal air traffic will be kept away from the vicinity of the launch site during launch.

8.5 Orbital Operations Phase

The objective of the orbital operation phase is to provide flexibility for performing orbital changes not necessarily associated with rendezvous. Major activities that occur during this phase are:

(1) External tank separation - Approximately 24 minutes
166
pg.2-46 after orbit insertion the orbiter separates from the external hydrogen/oxygen tank. Subsequently, the external tank de-orbits via a simple preprogrammed retro impulse that will cause the tank to enter the atmosphere and impact with acceptable dispersion.

(2) Ascent to operating orbit - Transfer from the
166
pg.2-9 50 x 100 n.m. orbit to the operating orbit as defined by the mission.

(3) Navigation updates and performance monitoring -
166
pg. 2-6 These activities are autonomous using vehicle software, displays,
166 controls, horizon scanner, star tracker and IMU. Backup system
pg.3-97 alignment is accomplished by an optical sighting device similar to the CSM crewman's optical alignment sight (COAS). The COAS is hand mounted on the window frame during spacecraft
153 operations.

8.5.1 Scene Content

8.5.1.1 Horizon. At orbital altitudes the horizon appears smooth and curved.

8.5.1.2 Terrain. Because of the various nominal orbital
166 pg.iii inclination angles (i.e., 28.5°, 55°, and 90°) the entire earth surface is potentially visible. Also, the day/night termination is potentially visible.

8.5.1.3 Celestial Bodies. Same as 8.3.1.3.

8.5.1.4 Orbiting Vehicles. These include us and Russian spacecraft, and "space junk" from previous flights.

8.5.1.5 Own Vehicle. As mentioned in Section 8.3.1.4, the external hydrogen/oxygen tank is visible in the mated configuration. The tank disposal sequence is shown in Figure 8.5-1. As indicated there, the tank is released, the orbiter trans-
36 pg.4-415 lates away from the tank and the tank's deorbit motor ignites on a time delay signal. Moreover, the pilot should view the

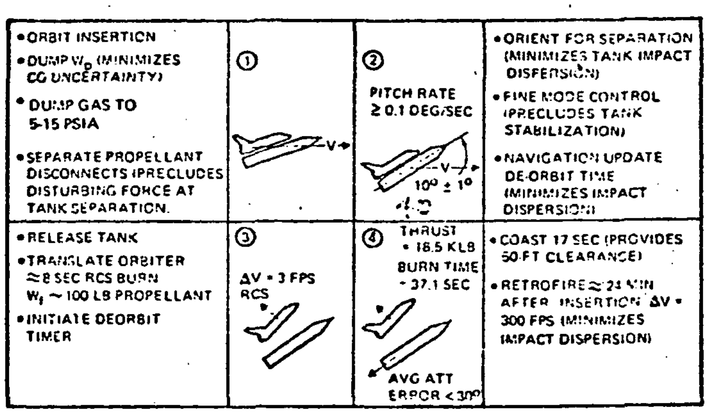

Figure 8.5-1 *Tank Disposal Sequence*

F-398-8-A

tank in order to determine the relative position of the tank with respect to the orbiter to verify a safe separation.

8.5.1.6 Atmospheric Effects. Same as 8.3.1.5.

8.5.2 Color

Colors that may be present during this phase include the black sky and various shades of green and brown of the earth. White clouds may also be present. There is the possibility that orbiting bodies may be visible during orbital operations. These bodies would probably be black and white, for the most part for thermal control.

8.5.3 Illuminators/Non-Illuminators

Examples of illuminators include sun, moon and the ignition of the external hydrogen/oxygen tank deorbit motor. Stars would be examples of non-illuminators.

8.5.4 Displacement

8.5.4.1 Translation

166
pg.2-9 $50 \leq$ altitude $\leq$ 500 n.m.

8.5.4.2 Rotation

In orbit, the vehicle can assume any attitude.

8.5.5 Velocity

166
pg.2-9 8.5.5.1 Translation

$25{,}500 \leq V \leq 28{,}000$ fps.

8.5.5.2 Rotation

166
pg.2-80 To be determined.

Note: Minimum attitude rate = 0.1°/sec.

8.5.6 Acceleration

8.5.6.1 Translation

To be determined.

166 pg.3-68 Note: Maximum V capability = 1000 ft/sec.

Burn time not specified

8.5.6.2 Rotation

166 pg.3-63

$0 \leq |\text{roll acceleration}| \leq 5^\circ/\text{sec}^2$

$0 \leq |\text{pitch acceleration}| \leq 2.5^\circ/\text{sec}^2$

$0 \leq |\text{yaw acceleration}| \leq 2.5^\circ/\text{sec}^2$

8.5.7 Assumptions

1) After orbiter/external tank separation, the orbiter is positioned such that the external tank is viewed in order to determine its relative position with respect to the orbiter.

8.6 High and Low Altitude Rendezvous Phase

The objective of the rendezvous phase is to fly to a co-orbit condition with another orbital vehicle. This phase includes: (1) orbital adjustment sub-phase, i.e., correct phasing with rendezvous target, (2) coelliptic sub-phase, i.e., to place the orbiter at the desired terminal condition prior to initiating an intercept trajectory, (3) terminal sub-phase, i.e., place orbiter on an intercept trajectory with the target and perform tracking to achieve a station keeping condition and (4) station keeping sub-phase, i.e., maintain a relative position in the near vicinity of the target vehicle.

166 pg.2-79 During rendezvous with an active cooperative target (Missions 1 and 2), target range, range rate and bearing data are used for navigation. The time in parking orbit is up to 17 orbits to achieve the proper phasing. For the single orbit retrieval mission rendezvous must be accomplished within thirty-five minutes. Rendezvous with a passive target employs
166 pg.3-97 ground tracking of the target combined with orbiter on-board navigation and, when required, range, range rate, and angle
166 pg.3-96 data from rendezvous sensors. The GN&C subsystem provides inertial navigation updated by stars and horizon sensors for autonomous orbital flight and by RF navigation aids (e.g.,
166 pg.3-97 TACAN) for rendezvous. As for Orbital Operations (Section 8.5), the backup system alignment is accomplished by an optical

sighting device, similar to the crewman's optical alignment sight (COAS).

8.6.1 Scene Content

8.6.1.1 Horizon

Same as 8.5.1.1.

8.6.1.2 Terrain

Same as 8.5.1.2.

8.6.1.3 Celestial Bodies

Same as 8.3.1.3.

8.6.1.4 Orbiting Vehicles

Rendezvous is required with the following orbiting vehicles: (1) space stations during space station resupply missions, (2) satellites during satellite retrieval missions, (3) space tug for orbit to orbit shuttle, (4) another orbiter during rescue missions and (5) a Russian manned vehicle. "Space junk" from previous flights may also be visible.

8.6.1.5 Atmospheric Effects

Same as 8.3.1.5.

8.6.2 Color

Same as 8.5.2.

8.6.3 Illuminators/Non-Illuminators

166
pg.3-160

The docking and runway lights on some orbiting vehicles are an additional example of non-illuminators with respect to those in Section 8.5.3. Also, examples of illuminators are

sun, moon and the orbiter's spotlights and floodlights, i.e., docking lights. This lighting system fulfills requirements for orbital visual acquisition and tracking, determination of gross range and range rate of orbiting vehicles during terminal rendezvous under all space lighting conditions. Moreover, the rendezvous phase usually begins in darkness.

8.6.4 Displacement

8.6.4.1 Translation

166 pg.2-9 $50 \leq$ altitude ≤ 500 n.m.

slant range ≤ 300 n.m.

8.6.4.2 Rotation

In orbit, the vehicle can assume any attitude.

8.6.5 Velocity

8.6.5.1 Translation

166 pg.209 $25,500 \leq V \leq 28,000$ pps

8.6.5.2 Rotation

166 pg.2-80 To be determined.

Note: Minimum attitude rate = 0.1°/sec.

8.6.6 Acceleration

8.6.6.1 Translation

166 pg.3-68 To be determined.

Note: Maximum V capability = 1000 ft./sec. Burn time is not specified.

8.6.6.2 Rotation

166
pg.3-63

$0 \leq |\text{ roll acceleration }| \leq 5^\circ/\text{sec}^2$

$0 \leq |\text{ pitch acceleration }| \leq 2.5^\circ/\text{sec}^2$

$0 \leq |\text{ yaw acceleration }| \leq 2.5^\circ/\text{sec}^2$

8.7 Docking and Undocking Phase

166 pg.3-96 The objective of a docking operation is to move from a station keeping mode to a docking condition with the rendezvous target.

The docking phase is the only phase that is conducted
166 pg. 2-9 in the manual mode only. The minimum time from rendezvous completion to docking is five minutes.

8.7.1 Scene Content

8.7 1.1 Horizon

Same as 8.5.1.1

8.7.1.2 Terrain

Same as 8.5.1.2

8.7.1.3 Celestial Bodies

Same as 8.3.1.3

8.7.1.4 Orbiting Vehicles

Same as 8.6.1.4

8.7.1.5 Atmospheric Effects

Same as 8.3.1.5

8.7.2 Color

Same as 8.5.2

8.7.3 Illuminators/Non-Illuminators

20 pg.IV-9 The orbiter vehicle is capable of manual docking to other orbiter vehicles during daylight or darkness. Otherwise, same as 8.6.3.

8.7.4 Displacement

8.7.4.1 Translation

166 pg.2-9 $50 \leq$ altitude ≤ 500 n.m.

slant range ≤ 10 n.m.

docking lateral misalignment = ± 0.5 ft.

8.7.4.2 Rotation

166 pg.2-9 In orbit, the vehicle can assume any attitude

docking angular misalignment = $\pm 5^{\circ}$

docking roll misalignment = $\pm 7^{\circ}$

8 7.5 Velocity

8.7.5.1 Translation

$25,500 \leq V \leq 28,000$ fps

maximum relative velocity at docking = ± 0.5 fps

8.7.5.2 Rotation

Same as 8.6.5.2

maximum velocity at docking = $\pm 1^{\circ}$/sec active vehicle

= $\pm 0.1^{\circ}$/sec passive vehicle

8.7.6 Acceleration

8.7.6.1 Translation

Same as 8.6.6.1

8.7.6.2 Rotation

Same as 8.6.6.2

REF. KEY

8.8 Payload Operations

The payload operations objective is to guide and control the orbiter as necessary to meet payload handling requirements. The following maneuvers could be encountered: docking, undocking and payload deploy/retrieve. The manipulator arms enables the remote manipulator system to perform the following tasks: (1) "capturing" orbital payloads, (2) docking the orbiter to orbital/payloads, (3) unload and deploy cargo from the orbiter cargo bay, (4) unloading space station module from orbiter transfer and dock module to space station and (5) assembling orbital payloads. The docking maneuver will be performed in a flyby manner rather than a head-on approach, so that in the event of a "redesignate and fly around" maneuver the two vehicles will not be on a collision course. In addition, the orbiter may be required to perform astronomical or other experiments with an attached payload.

22 pg.II-1

20 Pg.IV-10

22 pg. VIII-1

Since the two manipulator arms are identical, the actual design effort is limited to only one arm. The arm is designed so that only one arm is required to accomplish all tasks associated with capture, docking, or cargo handling operations. Thus, the remote manipulator system is redundant, in that if one arm fails, the other arm can be used to accomplish all the required tasks except orbital assembly. In particular, both arms are needed for orbital assembly. For example,

22 pg.II-4 capture and holding of the Large Space Telescope can be done with one arm while performing maintenance and module replacement tasks with the other arm. The nominal time for deployment

166 pg.2-9 of a 65,000 lb. payload is ten minutes. Also, the maximum time for deployment and retrieval of a 30,000 lb. payload is fifteen minutes total.

166 pg.3-160 There will exist as part of the remote manipulator system a minimum of five closed circuit television cameras and two TV monitors. The two TV monitors are located at the payload handling station. Two cameras are located near the terminator of each manipulator arm. Two TV cameras are mounted in the payload bay. The fifth camera is used within the crew module and mounted on the centerline of the docking axis at the docking port window.

166 pg.3-116 In addition to the two TV monitors and controls for the manipulator arms, the payload handling station provides controls for vehicle attitude and translation maneuvering. Also, the payload monitor/payload handling computer transforms the crewman's commands into appropriate rates of the seven arm joints until proper engagement is made.

8.8.1 Scene Content

8.8.1.1 Horizon

Same as 8.5.1.1

8.8.1.2 Terrain

Same as 8.5.1.2

8.8 1.3 Celestial Bodies

Same as 8.3.1.3

8.8.1.4 Orbiting Vehicles

Typical payloads encountered during payload deploy/
166 pg.3-155 retrieval maneuvers are: orbit-to-orbit shuttle, NASA point design tug, modular space station, sortie modules, SOAR, RAM, Large Space Telescope and Centaur and Agena stage Vehicles. Vehicles other than payloads that may require capture are: another orbiter during rescue missions and a Russian manned vehicle. Also "space junk" from previous flights may also be visible.

8.8.1.5 Own Vehicle

As mentioned in Section 8.2.1, the windows at the payload handling station provides visibility into the 15 ft. x 60 ft. payload bay (Fig.8.8-1).

8.8.1.5.1 Payload Bay Doors

36 pg. 4-368 The payload bay door is basically a clam-shell type with each half hinged along the longeron having a latching system at each end and along the mating centerline. The hinge is a theoretical center dual link type allowing 138° of door rotation.

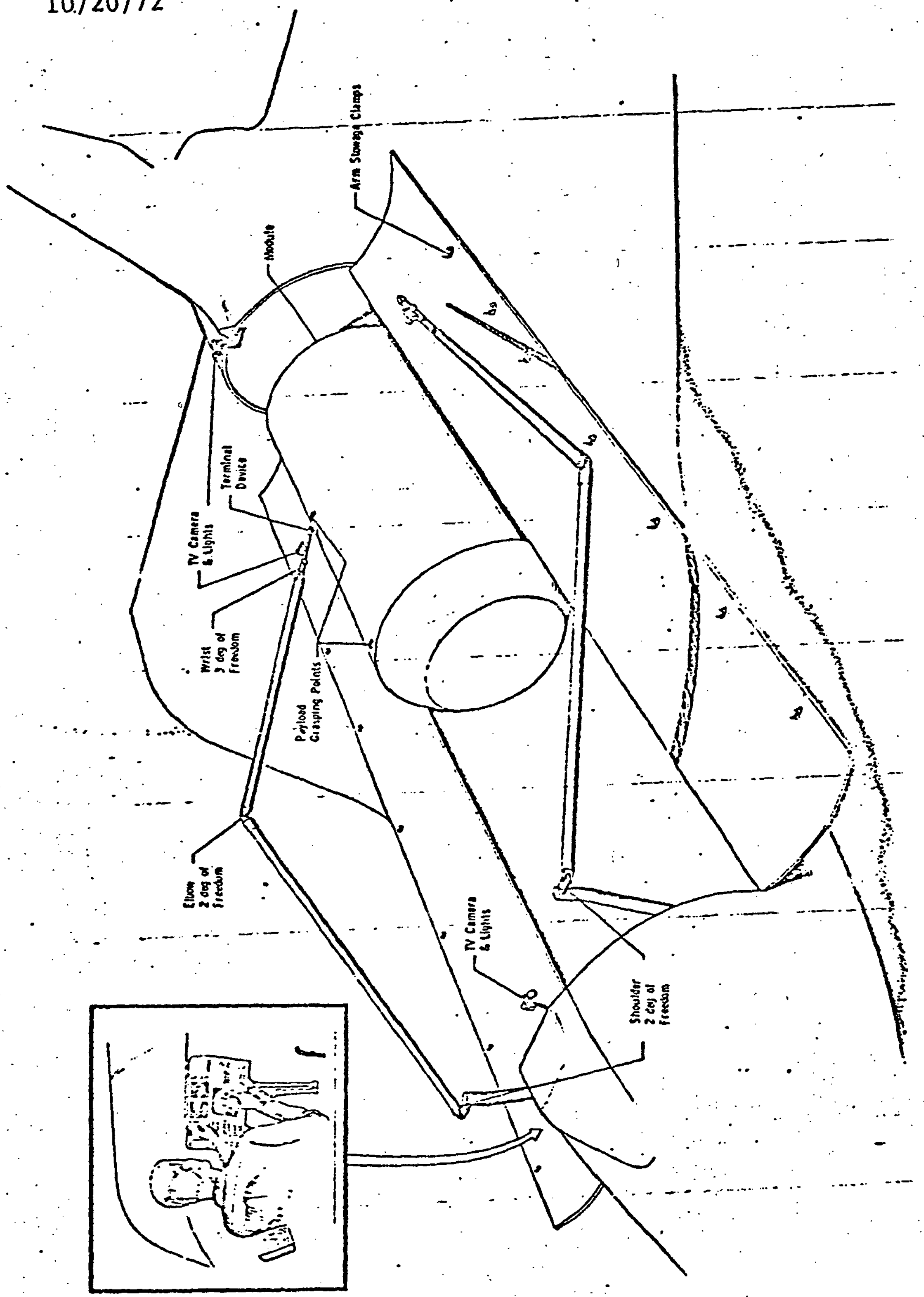

Figure 8.8-1 Shuttle Remote Manipulator System

Martin Marietta #59

8.8.1.5.2 Remote Manipulator System

22 Pg.II-3 Each arm is attached to the fuselage near the forward bulkhead of the payload bay. During launch and entry, the arms are stowed along the top of the payload bay. Each arm is extended, and attached at seven points to one of the payload doors, near the mating line between the doors (see Figure 8.8.-1). Each arm is attached to a different door. When stowed each arm occupies a cylindrical envelope 50 feet in length by 8 inches in diameter. In the event of a frozen joint failure, the arm possesses an explosive bolt device, so that the arm can be jettisoned to allow cargo bay doors to be closed for reentry.

Each arm possesses a shoulder, elbow, and wrist, with 2, 2 and 3 joints respectively. The shoulder degrees of freedom are pitch and yaw, the elbow degrees of freedom are roll and yaw; and the wrist degrees of freedom are yaw, pitch and roll (see Figure 8.8-2). Payloads are deployed by grasping them with a hand-like terminal device, lifting them out of the payload bay using the joint motors, and releasing them. Payloads are captured and retrieved similarly, the motors being useful for braking small relative velocites as well as returning payloads to the payload bay.

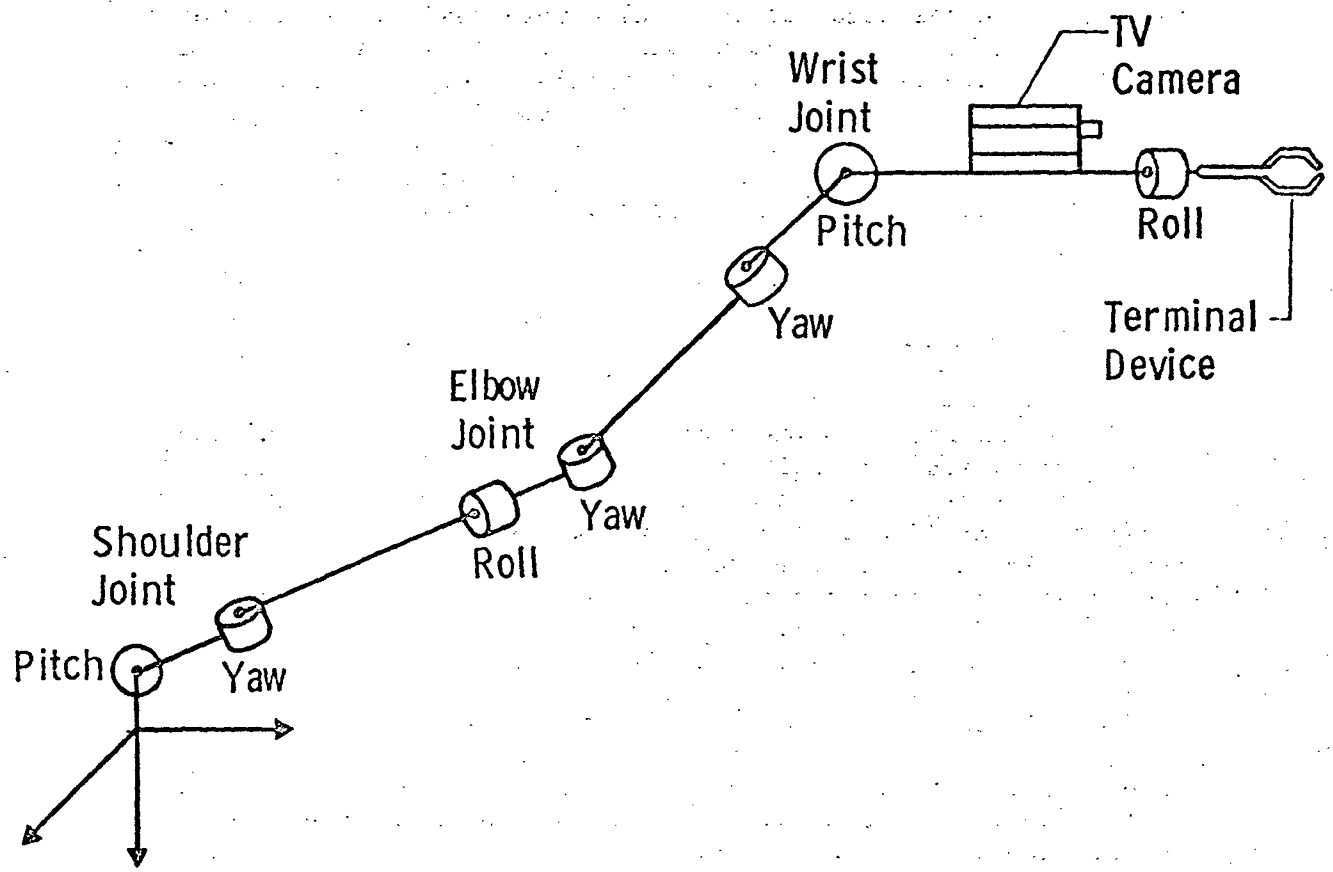

Figure 8.8.-2 RMS Joint Sequence

8.8.1.5.3 TV Cameras and Monitors

166 pg.3-159 The crewman utilizes direct and TV viewing while operating the manipulator arm controllers. The payload handling specialist's controls are discussed in the Crew Procedures Section. As is shown in Figure 8.8-2 the two TV cameras located near the terminator of each manipulator arm ensure a closer image of the target so that final closure and attachment may be accurately controlled. Two TV cameras mounted in the fore and aft sections of the payload bay provide remote viewing of the payload attachment and release and stowage operations as well as general viewing of the entire areas. The fifth camera mounted on the centerline of the docking axis at the docking port windows aids the manipulator operator to monitor alignment and range/range rate during manipulator controlled docking operations. The two TV monitors will be monoscopic and black and white. There is no requirement for a TV system with
22 pg. VIII-93 resolution greater than the obtainable standard 525 scan lines. Each monitor will have the standard ON/OFF, brightness, contract, and test controls. In addition any of the five TV cameras can be selected on either of the two TV monitors.

8.8.1.6 Atmospheric Effects

Same as 8.3.1.5

8.8.2 Color

Same as 8.5.2

8.8.3 Illiminators/Non-Illuminators

166 pg.3-160 The sun, moon, the payload bay floodlights and the manipulator arm spotlights are examples of illuminators. There are four 75 watt fluorescent payload bay floodlights (i.e., two on each end of the bayload bay) and two 100 watt tungsten halogen (i.e., one on each manipulator arm) manipulator arm spotlights. Stars are an example of a non-illuminator.

8.8.4 Displacement

8.8.4.1 Translation

22 pg. II-2

altitude $\leq$ 500 m.m.

max arm reach = 50 ft.

shoulder to elbow = 23.5 ft. = elbow to wrist

wrist to terminal device = 3 ft.

tip positional error accuracy = ± 2 inch

8.8.4.2 Rotation

In orbit, the vehicle can assume any attitude joint angular travel limits;

22 pg.VIII-3

shoulder: pitch = $\pm 200^{\circ}$, yaw = 130°

elbow: yaw = $\pm 155^{\circ}$, roll = $\pm 200^{\circ}$

wrist: pitch = $\pm 120^{\circ}$, yaw = $\pm 120^{\circ}$, roll = $\pm 200^{\circ}$

Note: See Figure 8.8.-3 for one arm shoulder to wrist envelope

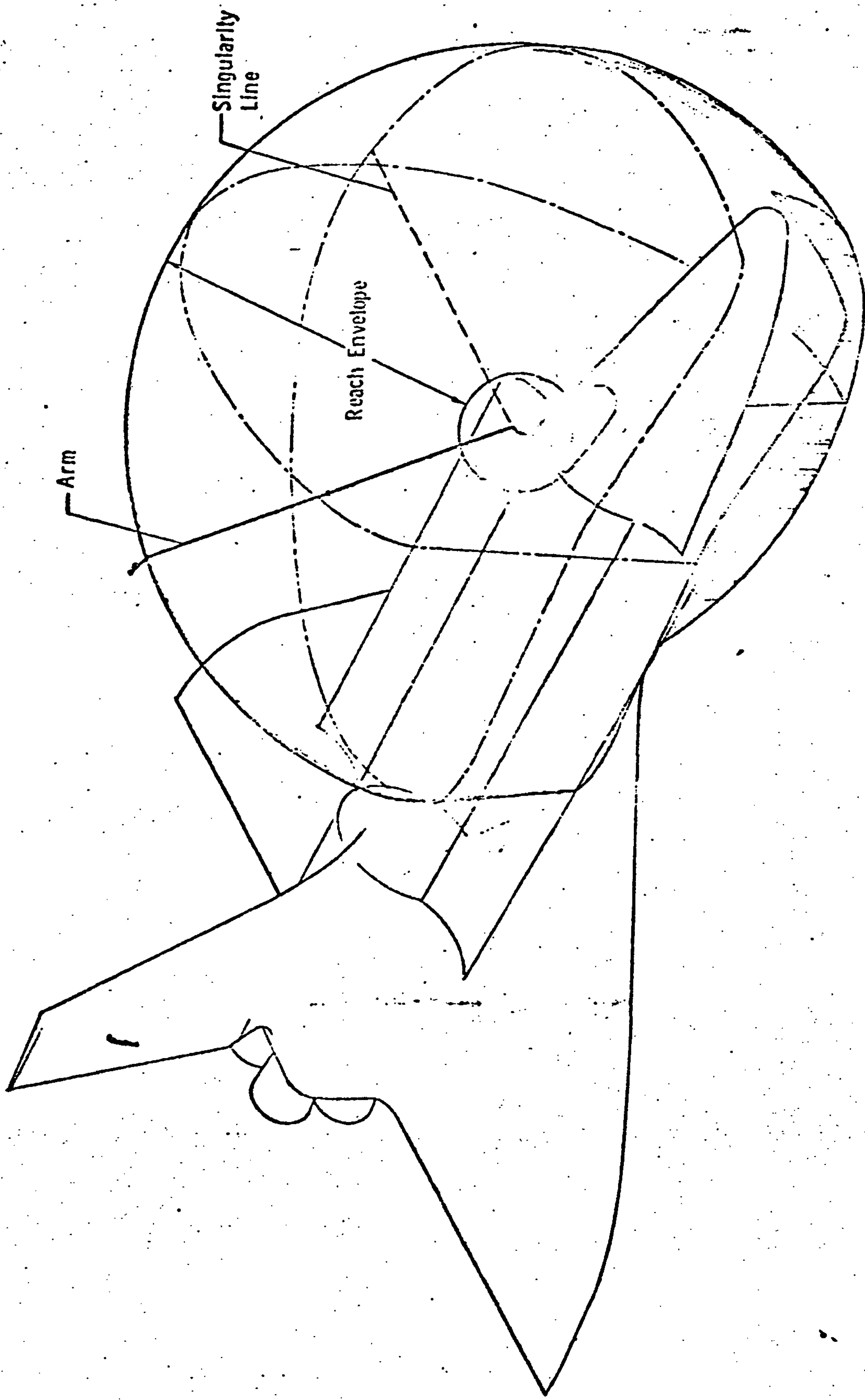

Figure 8.8-3 Wrist Reach Envelope Using One Arm

8.8.5 Velocity

8.8.5.1 Translation

$25{,}500 \leq V \leq 28{,}000$ fps

summation of tangential velocities at elbow,

22 pg. III-12 wrist, and tip gives: tip speed $\leq$ 2.5 fps (no load)

tip velocity error accuracy = ± 0.05 fps

22 pg. II-4 nominal relative velocity before arm is used to reduce relative velocity to zero = 0.1 fps

8.8.5.2 Rotation

22 pg. VII-12 shoulder: .3 rad/sec (no load)

.0035 rad/sec (full load)

elbow: .0565 rad/sec (no load)

.0066 rad/sec (full load)

wrist: .175 rad/sec (no load)

.0265 rad/sec (full load)

8.8.6 Acceleration

22 pg. VII-12

8.8.6.1 Translation

Maximum velocity can be reached in two seconds and summation of tangential acceleration at elbow, wrist, and tip gives: tip acceleration ≤ 1.25 ft/sec^2 (no load)

8.8.6.2 Rotation

Shoulder: 0.015 rad/sec^2 (no load)

Elbow: 0.028 rad/sec^2 (no load)

wrist: 0.087 rad/sec^2 (no load)

and for the vehicle itself same as 8.6.6.2.

8.8.7 Assumptions

1) After deployment of the payload a visual inspection will be conducted to determine the external conditions of the payload.

2) The remote manipulator system is based on two identical 50 foot long arms articulated at shoulder, elbow and wrist. The NAR Technical Proposal was inconsistent in specifying the length of the remote manipulator system arms. For example page 2-8 specifies a 35 foot manipulator arm and page 3-156 specifies a 45 foot arm.

8.9 De-Orbit Phase

The objective of the deorbit phase is to select a landing
site and perform the deorbit maneuver. Platform alignment and
31 pg.9-12 navigation are necessary and therefore included in this phase.
The primary landing point and the required orbit maneuver have
31 pg. 9-12-4 been determined from pre-phase planning computations. Since
the orbiter has a large cross range capability, de-orbit does
not require intersection of the landing site and the orbital
166 pg.2-75 plane. Based on the mission requirement definition, Mission 3
yields the largest crossrange requirements. The GN&C subsystem
166 pg. 3-96,97 provides inertial navigation updated by star and horizon
sensors for autonomous orbital flight. As for Orbital Operations
(Section 8.5), the backup system alignment is accomplished by
an optical signting device, similar to the crewman's optical
alignment sign (COAS).

The de-orbit burn will be targeted by the on-board compu-
31 pg.9-12-4 ter. Since, in general, several acceptable deorbit opportuni-
ties will exist, the on-board computer will display alternative
de-orbits to the crew, which will select a particular
opportunity based on entry crossrange, time to ignition, re-
quired delta-V, lighting conditions at landing, urgency of
return, etc.

8.9.1 Scene Content

8.9.1.1 Horizon

Same as 8.5.1.1

8.9.1.2 Terrain

Same as 8.5.1.2

8.9.1.3 Celestial Bodies

Same as 8.3.1.3

8.9.1.4 Orbiting Vehicles

Same as 8.5.1.4

8.9.1.5 Atmospheric Effects

Same as 8.3.1.5

8.9.2 Color

Same as 8.5.2

8.9.3 Illuminators/Non-Illuminators

Example of illuminators include the sun and moon. Stars would be examples of non-illuminators.

8.9.4 Displacement

8.9.4.1 Translation

$400{,}000 \leq$ altitude ≤ 500 m.m.

8.9.4.2 Rotation

In orbit, the vehicle can assume any attitude.

8.9.5 Velocity

8.9.5.1 Translation

166
pg.2-77

$25,500 \leq V \leq 28,000$ fps

8.9.5.2 Rotation

TBD

Note: Minimum attitude rate = 0.1^{o}/sec

8.9.6 Acceleration

8.9.6.1 Translation

TBD

Note: from a 500 m.m. orbit the burn time is 20 minutes resulting in a delta V = 800 ft/sec.

8.9.6.2 Rotation

Same as 8.5.6.2

8.10 ENTRY

The objective of the entry phase is controlling the orbiter angle of attack and bank angle to "fly out" the targeted crossrange and downrange within temperature, g-load, and skip-out constraints. A typical entry is characterized by the initially high constant angle of attack and large bank angle followed by a pullout where bank angle (and angle of attack, if necessary) are modulated to avoid heating and temperature constraints.

166 p. 2-61 & p. 2-77 The transition maneuver, that is, the transition from spacecraft (high angle of attack) to aerodynamic flight (maximum L/D) is a slow pitchdown maneuver using aerodynamic control in pitch and roll and is entirely accomplished in this phase. During pitchdown the rudder is activated and yaw control is obtained by a combination

166 p. 2-70 of RCS and flared rudder. At the end of transition, the rudder is fully effective and the RCS is deactivated.

20 p. IV-5 The crossrange capability of the orbiter is defined by the orbiter's state vector at the beginning and end

166 p. 2-75 of the entry phase. Mission 3 yields the most severe entry environment with a crossrange requirement of 1100 n.m.

166 p. 2-70 Both manual and automatic (autopilot) control modes are available throughout the entry phase. Steering 166 p. 3-97 information for entry is provided through visual interpretation of the backup G & N data on a cockpit cathode 26 p. 6-15 ray tube. Entry and transition will ordinarily be flown by the onboard computer.

166 p. 2-71 2-77 The duration of the entry phase is approximately 35 minutes, of which time transition is about 7 minutes.

8.10.1 Scene Content

8.10.1.1 Horizon

166 p. 2-77 In addition to Section 8.3.1.1, the horizon between orbiter altitude 400,000 ft to 250,000 ft appears in the side windows because of the flight path angle ($-1^o < \gamma < 0^o$) and the high angle of attack (approximately 35^o). Between 250,000 ft and initiation of transition, a large roll angle is maintained and the horizon appears in the front windows.

8.10.1.2 Terrain

This includes all the visible features of the earth's surface, both natural and artificial. The terrain scene depends upon the landing site (e.g., KSC 166 p. 2-77 and WTR). Between 250,000 ft and initiation of transition, the terrain including cloud cover is dominant in the lower side window because of the large bank angle requirement

($-75^{\circ} \leq \varphi \leq 75^{\circ}$) during this region.

The loss of the view of both the terrain and horizon may be lost during the high temperature region of entry.

8.10.1.3 Celestial Bodies

Same as 8.3.1.3

8.10.1.4 Atmospheric Effects

Same as 8.3.1.5

8.10.2 Color

Colors that may be present during this phase include the blue-green of the ocean, various shades of green and brown from the natural landscape and the colors of cultural objects. The white clouds will also be present. Also, the color of the sky will gradually change from black to blue.

8.10.3 Illuminators/Non-Illuminators

Examples of illuminators during the entry phase are the sun and moon. Examples of non-illuminators are the stars. The entry phase could occur during daylight or darkness.

8.10.4 Displacement

8.10.4.1 Translation

$70{,}000 \leq$ transition altitude $\leq 160{,}000$ ft

$50{,}000 \leq$ entry altitude $\leq 400{,}000$ ft

For WTR: entry north to south

166 p. 2-77 $0 \leq x_E \leq + 5000$ n.m.

$-1100 \leq y_E \leq 1100$ n.m.

For KSC: entry west to east

$0 \geq y_E \geq - 5000$ n.m.

$-1100 \leq x_E \leq 1100$ n.m.

8.10.4.2 Rotation

166
p. 2-77 $-75^o \leq$ bank angle $\leq 75^o$

p. 2-62 $0^o \leq$ pitch angle $\leq 50^o$

p. 2-71 $-5^o \leq$ slide slip angle $\leq 5^o$

p. 2-62, 77 $10^o \leq$ angle of attack $\leq 50^o$

p. 2-77 $-10^o \leq$ flight path angle $\leq 0^o$

8.10.5 Velocity

8.10.5.1 Translation

$900 \leq V \leq 26{,}000$ fps

$1400 \leq V \leq 8{,}500$ fps (during transition)

At WTR: entry north to south

p. 2-77 $50 \leq |\dot{z}_E| \leq 600$ fps

$0 \leq |\dot{x}_E| \leq + 26{,}000$ fps

$0 \leq |\dot{y}_E| \leq 7{,}500$ fps

At KSC: entry west to east

$50 \leq |\dot{z}_E| \leq 600$ fps

$0 \leq |\dot{y}_E| \leq 26{,}000$ fps

$0 \leq |\dot{x}_E| \leq 7{,}500$ fps

8.10.5.2 Rotation

166 p. 2-69

$0 \leq |p_B| \leq 20^o/\text{sec}$

$0 \leq |q_B| \leq 5^o/\text{sec}$

$0 \leq |r_B| \leq 5^o/\text{sec}$

8.10.6 Acceleration

8.10.6.1 Translation

p. 3-7 & p. 2-77

Max. acceleration = 3 g's

$|\ddot{z}_E| \leq 66$ ft/sec^2

$|\ddot{x}_E| \leq 50$ ft/sec^2

$|\ddot{y}_E| \leq 50$ ft/sec^2

8.10.6.2 Rotation

$0 \leq |\dot{p}_B| \leq 1.5$ rad/sec^2

$0 \leq |\dot{q}_B| \leq 0.5$ rad/sec^2

$0 \leq |\dot{r}_B| \leq 0.5$ rad/sec^2

8.10.7 Assumptions

1) Land Field Earth Axes System - The origin of this axes system lies on the surface of the earth fixed at the intersection of the runway threshold and centerline. The x_E axis is positive North, y_E is positive East and the z_E axis is positive toward the center of the earth.

REF. KEY

8.11 Approach and Landing Phase

166 pg.2-73 The objective of this phase is two-fold. Initially, during the terminal approach sub-phase the orbiter is flown with a maximum L/D to the desired glideslope intercept following an optimal path dependent on energy available. Subsequently, the final approach sub-phase begins at an altitude of 10,000 ft. and the orbiter is controlled to a 15° glideslope until 1050 feet, where the standard 3° glideslope is initiated. Orbiter landing is part of the final approach sub-phase.

166 pg.3-97 Both manual and automated (autopilot) control modes are available during this phase. Automatic landing is accomplished via a computed flight path generated in the GN&C computer using the inertial navigation system
166 pg.2-5 for reference with continuous updates from TACAN and instrument landing system (ILS). Range and bearing information is obtained via TACAN antennas throughout
21 pg.59 this phase and the ILS antennas are deployed at 10,000 ft.
166 pg.3-97 Radar altimeter updates are used near touchdown (approximate altitude range 2500 feet to touchdown). The two segment (15 and 3 degree) glideslope approach requires separate ground ILS transmitters for each segment.

166 pg.2-73 Two flare maneuvers are conducted during the final approach. At 1050 feet, the first flare results in a transition from a 15° glideslope to a 3° glideslope. The final flare occurs at an altitude of 80 feet so that the approach velocity decreases to the design touchdown velocity and the approach sink rate decreases to the design touchdown sink rate.

166 pg.2-61 At 10,000 ft. the landing gear is deployed in preparation for landing after it has been determined that a satisfactory approach has been established.

166 pg.2-73 Two concepts have been evaluated and are acceptable to compensate for crosswinds during approach and landing. They are: the slip concept requiring up to approx. 7° of bank angle to maintain vehicle along the runway centerline, and the decrab maneuver initiated 2 seconds before touchdown requiring up to 10° of rudder and aileron control inputs to offset rolling moment resulting from sideslip.

166 pg.iii, 2-56 The orbiter vehicle will have an air breathing propulsion system (ABPS) installed for early orbital pg.2-56 development flights and subsequent supply missions (e.g., Mission 2). The ABPS provide fifteen minutes

loiter flight capability at 10,000 feet or alternately provide the capability to perform a go-around at the landing site without prior loiter. For early develop-
166 pg.3-77 ment flight, assisted air starts will be initiated at 40,000 feet, the upper limit of the air-start envelope. For supply missions, air start will be delayed to 25,000 feet, which will provide sufficient time during descent for engine start and operational check prior to initiating the planned 15 minute loiter flight at 10,000 feet altitude.

The duration of a nominal approach and landing is
166 pg.2-77 approximately 10 minutes. If the vehicle has ABPS installed the duration can increase to 25 minutes.

8.11.1 Scene Content

8.11.1.1 Horizon

This refers to the boundary between the earth and skyfield, It is usually rough at low altitudes, due to the presence of terrain features.

8.11.1.2 Terrain

This includes all the visible features of the earth's surface, both natural and unnatural. The land-
166 pg.5-37 ing strip at KSC is a 10,000 ft. x 150 ft. runway with a 1500 ft. overrun, tower, operations building, utilities, runway lighting, ILS and navigation aids. This runway

will be a new construction northwest of VAB. The pilot's
166 pg.2-91 perception of the horizon and runway in unpowered approach and landing is considered to be critical in order to
166 pg.2-5 safely accomplish the task. Also, upon descending along the 15^{o} glideslope, acquisition of visual references are required at the decision altitude (unspecified) (with ABPS only) such that a missed approach could be initiated when these visual references have not been established with the runway environment, thereby signifying that the vehicle is not in position to execute a normal landing. Along the 3^{o} slideslope, the pilot aligns the vehicle with the VFR flight path.

8.11.1.3 <u>Celestial Bodies</u>

Same as 8.3.1.3

8.11.1.4 <u>Atmospheric Effects</u>

Same as 8.3.1.5

8.11.1.5 <u>Other Aircraft</u>

Depending on airspace restrictions imposed on other air traffic, such traffic could be visible during approach and landing.

8.11.2 Color

Colors that may be present during this phase include the blue sky, the blue-green of the ocean, various shades of green and grown from the natural landscape. White clouds may also be present.

The Category II runway lighting includes: red (e.g., red barrettes on each side of the centerline), white (e.g., touchdown zone), green (e.g., runway threshold), yellow (e.g., runway remaining edge lights) and blue (e.g., taxiway edge at intersection).*

8.11.3 Illuminators/Non-Illuminators

Similar to Section 8.10.3 with approach and runway lighting and runway lights of other aircraft being an additional example of non-illuminators. The approach and landing phase could occur during daylight or darkness.

8.11.4 Displacements

8.11.4.1 Translation

$0 <$ approach and landing altitude $\leq 50{,}000$ ft.

$1050 < 15^{\circ}$ glideslope altitude $\leq 10{,}000$ ft.

$0 < 3^{\circ}$ glideslope altitude < 1050 ft.

Eye point above local horizontal = 24.5 ft. (vehicle at rest on runway).

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*International Civil Aviation Organization Annex 14 with Attachments. Fifth Edition, May 1969.

Ground track for approach and landing to be determined (TBD). Figure 8.11-1 illustrates a typical approach and landing (without ABPS).

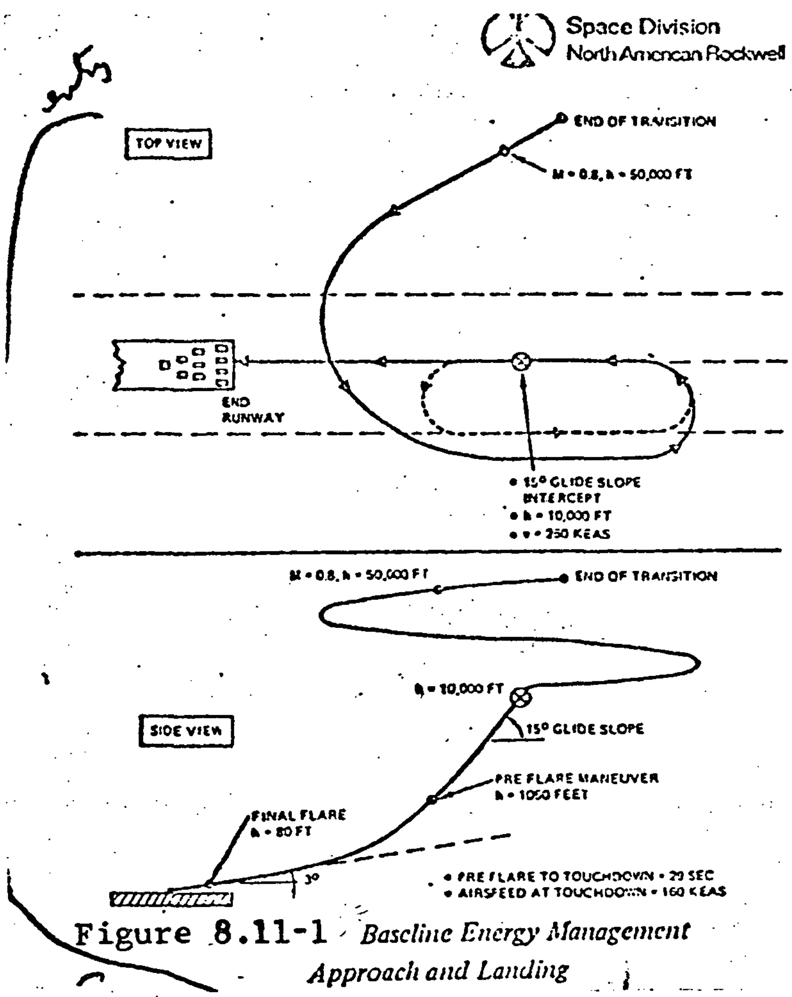


Figure 8.11-1 *Baseline Energy Management Approach and Landing*

8.11.4.2 Rotation

166
pg. 2-62 $-30^{\circ} \leq$ bank angle $\leq +30^{\circ}$

pg. 2-62, 3-31 $-3^{\circ} \leq$ pitch angle $\leq 20^{\circ}$

pg. 2-62 $-10^{\circ} \leq$ slide slip angle $\leq 10^{\circ}$

pg. 2-62 Tail scrape angle at touchdown = 18°

pg. 2-62 Nominal angle of attack at touchdown = 13°

pg. 2-65 $-20 \leq$ flight path angle ≤ 0

8.11.5 Velocity

8.11.5.1 Translation

pg. 2-62, 2-77 $250 \leq$ velocity from 50,000 ft to 10,000 ft. $\leq$ 600 kts

pg. 2-55 $140 \leq$ velocity from 10,000 ft to touchdown $\leq$ 250 kts

pg. 2-62 Design touchdown sink rate = 0 to 10 fps.

8.11.5.2 Rotation

166 $0 \leq |p_B| \leq 20^{\circ}$/sec

pg. 2-69 $0 \leq |q_B| \leq 5^{\circ}$/sec

$0 \leq |r_B| \leq 5^{\circ}$/sec

8.11.6 Acceleration

8.11.6.1 Translation

36
pg. 4-245 $0 \leq$ acceleration ≤ 40 ft/sec^2

8.11.6.2 Rotation

$$0 \le |\dot{p}_B| \le 1.5 \text{ rad/sec}^2$$

$$0 \le |\dot{q}_B| \le 0.5 \text{ rad/sec}^2$$

$$0 \le |\dot{r}_B| \le 0.5 \text{ rad/sec}^2$$

8.11.7 Assumptions

1) Same as assumption (1) for Section 8.10.7.

2) Same as assumption (2) for Section 8.4.7.

8.12 Ferry Flight Phase

The objective of the ferry operations is to fly the
20 pg.IV-10 vehicle from one airport to another. For ferry flights the orbiter vehicle will be capable of operating in and out of air fields that have runways equivalent to 10,000 feet long and 150 feet wide at sea level and 13,000 foot runways at 4,000 foot elevations. The orbiter will be capable of taking
166 pg.1-2 off and landing on such runways, allowing for hot day temperature, wet surfaces, and specified wind conditions. The orbiter will be able (via six stops or aerial refueling (technique not specified)) to perform ferry flights within the continental United States from East Coast to West Coast, and from point of final assembly to test and launch sites.

For ferry flights the ABPS system will consist of the
166 pg.3-75 orbital module plus two additional engines for a total of four air breathing engines. The orbiter will be capable of main-
20 pg.IV-21 taining level flight with one engine out at 10,000 feet
166 pg.2-55 altitude or higher. In the ferry configuration, the orbit maneuvering system pods including aft RCS modules are replaced with aero fairing.

166 pg.3-32 During the ferry/horizontal flight test configuration, the landing system is capable of drift landings with peak ground wind speeds of 35 knots from any azimuth. The ferry configuration also is used to conduct the horizontal flight test program.

8.12.1 Scene Content

8.12.1.1 Horizon

The horizon will appear rough due to the presence of terrain features.

8.12.1.2 Terrain

This includes all the visible features of the earth's surface, both natural and unnatural. The various landing strips are prominent during takeoff and landing. Also, visual references near the landing strips are required in order to determine whether a missed approach should be initiated.

8.12.1.3 Celestial Bodies

These include sun, moon and stars. The stars will only be visible during night ferry flights. The sun also casts shadows.

8.12.1.4 Other Aircraft

The in-flight refueling technique, either boom refueling or probe/drogue will be determined. The belly lights of the tanker aircraft, to determine relative position, and either the "basket" light for probe/drogue or the tanker's boom for boom refueling are predominent. Also, depending on airspace imposed on other aircraft traffic, such traffic could be visible during ferry flights.

8.12.1.5 Own Aircraft

If probe/drogue is the selected technique for in-flight refueling, the probe will be visible.

8.12.2 Color

Same as 8.11.2.

8.12.3 Illuminators/Non-Illuminators

In addition to 8.11.3, the tanker's belly lights are an additional example of non-illuminators. If probe/drogue technique is used the "basket" light and the probe light are additional examples of illuminators. Ferry flights could be conducted during daylight or darkness.

8.12.4 Displacement

8.12.4.1 Translation

166 pg.2-62 & pg.IV-21

ferry range = 400 n.m.

maximum altitude > 10,000 ft.

Eye point above local horizontal = 24.5 ft. (vehicle at rest on runway).

8.12.4.2 Rotation

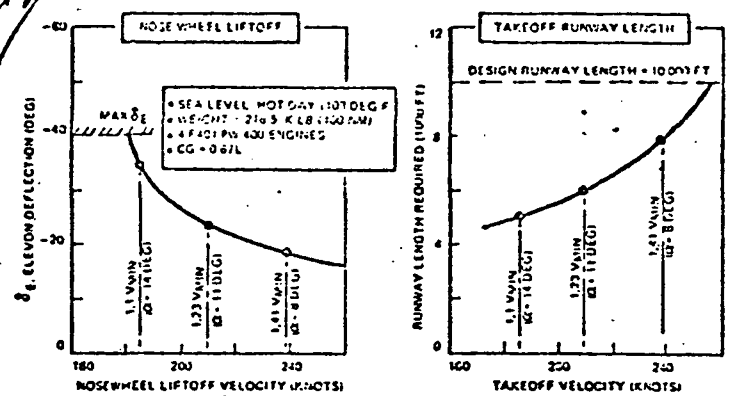
Same as 8.11.4.2.

8.12.5 Velocity

8.12.5.1 Translation

V_{min} is defined as minimum liftoff speed at tail-scrape altitude for the heaviest ferry weight configuration without ground or thrust effects (see Figure 8.12-1).

ferry



Ferry Takeoff Performance Attained

Figure 8.12-1

Maximum velocity in flight = TBD

8.12.5.2 Rotation

Same as 8.11.5.2.

8.12.6 Acceleration

8.12.6.1 Translation

To be determined.

8.12.6.2 Rotation

Same as 8.11.6.2.

8.12.7 Assumptions

1) The orbiter's rotation capability during approach and landing is equivalent to the orbiter's rotation capability during the ferry phase.

2) The 15^{o} glideslope will not be utilized during the landing portion of the ferry flight. Rather the conventional 3^{o} glideslope only will be used.

3) Same as assumption (1) for Section 8.10.7.

9.0 Cue Requirements

Aural simulation constitutes an important adjunct to providing the astronaut with a comprehensive spectrum of sensory indications relating to the operational performance characteristics of a flight. It has been shown that under certain conditions the Pilot can detect a change in an operating parameter from the resulting change in the sounds before the condition manifests itself in any visual indication or proprioceptive cue. An aural cue simulation subsystem is required in the SMS to provide real-time simulation of the actual acoustical environment with sufficient scope and realism so that the crew in training is supplied with aural cues which aid in the accomplishment of critical management tasks. The aural cues are restricted to those cues which relate directly to important space shuttle management procedures.

At the time of this study, sufficient data are not available to precisely define the sounds which would provide aural cues to the crew members. Only when the frequency range and decibel level of the various system noises are determined can an evaluation be made of the aural cues required in the SMS. Based on reference data currently available, the following is a general description of the anticipated sounds which would provide aural cues to the shuttle crew.

9.1 Propulsion Cues

Aural cues will be generated by both liquid fuel and solid rocket engines. The noise cues are broken down in the following paragraphs by each originating source.

9.1.1 Main Rocket Engines

The main liquid fuel rocket engines have sounds associated with burning, to include rough burn. The engines are throttlable over a range. However, the noise level will only decrease one-half of full volume when throttled. Although the engines have both fuel and oxidizer pumps, it is doubtful if these pumps would be heard over engine ignition. There are three main engines to be simulated, each of which may be started at a separate time. Prior to start and post firing, metal expansion and contraction noises are expected. Prior to reentry the main rocket engines will be purged of residuals with inert gas. This purging operation will probably be heard as a muted gas expansion.

9.1.2 Solid Rocket Motors

There are two 156-inch solid rocket motors which will produce thrust sound and vibration. Thrust level of each SRM is approximately 3.5 million pounds. Start-up and shut-down transient noises are not required from the nature of the SRM burning. Upon thrust termination of these motors, they will be separated from the orbiter and tank using auxiliary rockets.

Noises associated with rocket firing and burn should be audible to the crew. Mechanical noises associated with separation should not be heard over the separation rocket noise.

9.1.3 Airbreathing Engines

The airbreathing engines are stored internally in the shuttle vehicle prior to engine start. A door cover thump and hydraulic actuator sound will accompany engine deployment. Once deployed, booster pump whines and a hydrazine explosion will be heard during engine start. Following start-up, a turbine whine will build up to run level and continue until shutdown. During airstart, this whine will also be heard. At this time, it is assumed that the jet engines will have thrust reversal capability and the accompanying noise.

9.1.4 Abort Solid Rocket Motors

Two solid rocket motors attached to the orbiter aft fuselage provide the rapid start and high thrust necessary to accomplish orbiter separation from the booster, SRM's and external tank in the event of an abort between 0 and 30 seconds. The rockets burn for approximately 21 seconds with an average thrust of 385,000 pounds. Ignition, burn and shutdown sounds will be associated with these motors. It is assumed that these rockets will be jettisoned by explosive devices which require a muted thump cue. In a normal mission, the motors will be jettisoned unused 30 seconds from liftoff.

9.2 System Equipment Cues

The deployable, external fuel-oxidizer tank would create noises associated with pyrotechnic line separators, fuel and oxidizer venting prior to separation, and separation system pneumatic and mechanical thumps.

Reaction control thruster jets provide attitude control and three-axis translational capability during orbital and entry phases of the mission. The thrusters are located in the orbiter nose section and each of the aft OMS pods. The jets will cause a thump sound on activation, identifiable as to direction.

Docking sounds are required for the mechanics of door opening, docking ring extension, mating, locking and the pneumatic shock absorber system. More definition is required to determine the metallic sounds to be simulated and the shock absorber pneumatic sounds.

The sounds associated with the payload area and payload deployment involve the latching and unlatching of payload doors, payload and radiator units. Hydraulic sounds will be associated with radiator deployment, door mechanics, and the payload manipulator. Various levels of mechanical matings (thumps) are associated with the door opening and closing, radiator deployment and retraction, manipulator mating and stowage, and payload mating with external vehicles, or return of payloads to the payload bay. Emergency jettisoning of the

manipulator would create noises associated with pyrotechnic separators.

The electrical generators operating off the APU's will produce a 400 hertz hum. This will probably appear as a background noise. There will be an increased level of DC electrical motor sound during payload door opening without APU hydraulic power. The APU will have an explosive start-up sound with a 12,000 hertz run mode background noise. There are three APU's which may be started independently.

Fuel cell venting from two or four units will be heard as pressure builds up to trip limit. This sound will probably be a pop (valve opening) followed by an air hiss.

Environmental air-conditioning sounds heard when the cabin is pressurized will be valves popping - high pressure air release - and air pressurization or evacuation during EVA/IVA activity. The volume of sound will be dependent upon air density.

The aerodynamic control surfaces should generate a hydraulic motor hum when driving from one position to another. In atmosphere, an air flow noise should be generated which is a function of dynamic pressure and the amount of total surface deflection.

Deployment of the speed brakes by the hydraulic system should create a thump. An air flow noise should be associated

with the speed brake while deployed in the atmosphere. The air flow noise intensity is variable as a function of dynamic pressure.

The drag chute system should cause two minor sounds; a thump on opening of the drag chute container system and a second thump on opening of the main chute.

9.3 Aerodynamic Cues

Aerodynamic control surfaces will create aural cues of wind noise, turbulence and buffeting. During reentry phases it is expected that metal expansion and contraction will cause various popping and cracking sounds.

9.4 Caution and Warning Cues

The caution and warning system is largely undefined at this time. It is assumed that the system will parallel existing space and aircraft systems. The caution and warning system will provide a means of monitoring critical parameters. In the event of an anamolous condition, a tone will be generated in addition to a light identifying the problem area. Other standard cues for warning, emergency fire and rapid loss of pressure are also required.

9.5 Landing Gear Cues

The landing gear system will have sounds associated with the gear doors opening and closing (hydraulic cylinder activation). When the gear door begins opening, an air noise should

be generated. The volume would be dependent upon air density. A mechanical thump would be associated with the gear door opening or closing. The gear deployment and retraction will create sounds associated with hydraulic motor activation. When the gear is fully extended or retracted, a mechanical thump should be heard. Noises will be connected with operation of the beakes. Noises would also result from tire vibration or wobble at high speed and tire contact with the runway on landing.

9.6 Malfunction Cues

Aural cues may be associated with some malfunctions, e.g., engine failure would result in a decrease in noise level normally heard. When subsystems have been selected for the space shuttle, potential system malfunctions will be identified. Once identified, an analysis should be made of the relationship of audio cues to the identification of the malfunction.